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COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
APR 70 G L BODHAINE, H D HAFTERSON

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Columbia–North Pacific Region

Comprehensive Framework Study
of Water and Related Lands

APPENDIX V
VOLUME 1

WATER RESOURCES

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PACIFIC NORTHWEST RIVER BASINS COMMISSION
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This appendix is one of a series making up the complete Columbia-North Pacific Region Framework Study on water and related lands. The results of the study are contained in the several documents as shown below:

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Summary Report

Appendices

I. History of Study

II. The Region

III. Legal & Administrative Background

IV. Land & Mineral Resources

V. Water Resources

VI. Economic Base & Projections

VII. Flood Control

VIII. Land Measures & Watershed Protection

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Pacific Northwest River Basins Commission
1 Columbia River
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April 1970

G. L. Bodhaine, H. D. Hafterson,
M. J. Mundorff John Summersett

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Columbia-North Pacific Technical Staff
Pacific Northwest River Basins Commission
Vancouver, Washington

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APPENDIX V
Water Resources

Prepared under the direction of the
Columbia-North Pacific Technical Staff
by the
Hydrology Work Group

G. L. Bodhaine, Chairman (1966-1968)
John Summersett, Chairman (1969)

Department of Agriculture
W. A. Post, FS
D. R. Wagoner, SCS

Department of the Army
John Summersett, Corps
D. M. Rockwood, Corps

Department of Commerce
G. L. Sternes, ESSA

Department of the Interior
G. L. Bodhaine, GS
H. D. Hafterson, BR
F. A. Limpert, BPA
L. A. Reed, FWPCA
C. E. Veirs, FWPCA

Idaho
A. C. Robertson, IWRB
C. E. Tappen, IWRB

Montana
Orrin Ferris, MWRB
A. J. Mancini, MWRB
A. D. McDermott, MWRB

Nevada
E. J. DeRicco, Department of Conservation & Natural Resources
B. J. Vasey, "

Oregon
J. W. Carver, Jr.
State Engineer's Office
P. C. Klingeman, OSU
C. L. Rempel
State Engineer's Office
W. D. Wilkinson, OSU

Utah
E. B. Haycock
Division of Water Resources

Washington
M. E. Garling
Department of Water Resources

Wyoming
F. A. Bishop
State Engineer's Office
Myron Goodson, Water Development
D. L. Simmons
State Engineer's Office
C. E. Tangeman
State Engineer's Office

Principal Authors' Contribution

G. L. Bodhaine Geological Survey	Regional Summary One Subregion Section (11)
H. D. Hafterson Bureau of Reclamation	Five Subregion Sections (2, 3, 4, 5, 6)
M. J. Mundorff Geological Survey	Ground Water
John Summersett Corps of Engineers	Six Subregion Sections (1, 7, 8, 9, 10, 12)

This appendix to the Columbia-North Pacific Region Framework Report was prepared at field level under the auspices of the Pacific Northwest River Basins Commission. It is subject to review by the interested Federal agencies at the departmental level, by the Governors of the affected States, and by the Water Resources Council prior to its transmittal to the President of the United States for his review and ultimate transmittal to the Congress for its consideration.

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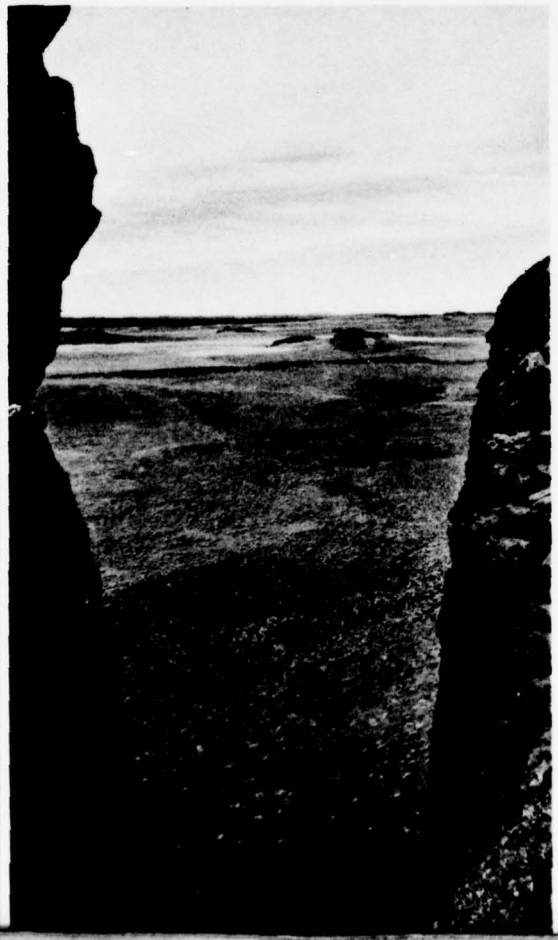
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CONTENTS

APPENDIX V
WATER RESOURCES

	Page No.
Tables	vi
Figures	xi
INTRODUCTION	1
Purpose and Scope	1
Purpose	1
Scope	1
Definition of Present Conditions	2
Relationship to Other Parts of the Report	3
Description of the Region	3
Acknowledgments	6
REGIONAL SUMMARY	7
Climate	7
Weather Records	7
Precipitation	8
Temperature	8
Wind	13
Evaporation	13
Evapotranspiration	15
Storms	15
Humidity	17
Sunshine	17
Surface Water	17
Quantity	18
Quality	51
Ground Water	62
Relation of Ground Water to Geology	63
Well Yields	64
Basis for Statements on Quality of Ground Water	65
Areal Distribution of Ground Water	67
Aquifer Units and Their Hydrologic Characteristics	68
Potential Aquifers	81
Water in Storage	82
Recharge and Discharge	85
Ground-Water Withdrawal and Use	92
Future Availability	94
Artificial Rehcarge	98
Ground-Water Rights	98
Relation Between Surface and Ground Water	102
Needs for Additional Hydrologic Data	103
Climatological Data	103
Streamflow and Stage	104

CONTENTS

	Page No.
Water Quality	106
Water Use	108
Ground Water	109
Ground-Water Surface-Water Relationships	110
Time of Travel	110
Drainage Areas	110
Technological Advances	111
Forecasting	111
Evaporation Suppression	112
Vegetation Management	112
Subsurface Reservoirs	114
Glaciers	115
Alpine Snowfields	117
Weather Modification	118
Nuclear Explosives	119
Desalination	120
SUBREGION 1, CLARK FORK-KOOTENAI-SPOKANE	123
Hydrologic Framework	123
Climate	125
Surface Water	129
Quantity	130
Quality	190
Ground Water	196
Aquifer Units and Their Hydrologic Characteristics	196
Present Use and Future Availability	205
Artificial Recharge	206
Water Rights	206
Relationship Between Surface and Ground Water	207
SUBREGION 2, UPPER COLUMBIA	211
Hydrologic Framework	211
Climate	212
Surface Water	217
Quantity	217
Quality	255
Ground Water	261
Aquifer Units and Their Hydrologic Characteristics	261
Present Use and Future Availability	273
Artificial Recharge	273
Water Rights	274
Relationship Between Surface and Ground Water	274
SUBREGION 3, Yakima	277
Hydrologic Framework	277
Climate	278

CONTENTS

	Page No.
Surface Water	284
Quantity	284
Quality	324
Ground Water	331
Aquifer Units and Their Hydrologic Characteristics	331
Present Use and Future Availability	339
Artificial Recharge	342
Water Rights	342
Relationship Between Surface and Ground Water	343
SUBREGION 4, UPPER SNAKE	345
Hydrologic Framework	345
Climate	346
Surface Water	352
Quantity	352
Quality	365
Ground Water	396
Aquifer Units and Their Hydrologic Characteristics	397
Present Use and Future Availability	407
Artificial Recharge	409
Water Rights	410
Relationship Between Surface and Ground Water	412
SUBREGION 5, CENTRAL SNAKE	415
Hydrologic Framework	415
Climate	416
Surface Water	422
Quantity	422
Quality	456
Ground Water	461
Aquifer Units and Their Hydrologic Characteristics	462
Present Use and Future Availability	471
Artificial Recharge	472
Water Rights	473
Relationship Between Surface and Ground Water	474
SUBREGION 6, LOWER SNAKE	477
Hydrologic Framework	477
Climate	478
Surface Water	483
Quantity	483
Quality	523
Ground Water	530
Aquifer Units and Their Hydrologic Characteristics	530
Present Use and Future Availability	537
Artificial Recharge	538
Water Rights	538

CONTENTS

	Page No.
Relationship Between Surface and Ground Water	541
SUBREGION 7, MID COLUMBIA	545
Hydrologic Framework	545
Climate	547
Surface Water	553
Quantity	553
Quality	608
Ground Water	615
Aquifer Units and Their Hydrologic Characteristics	616
Present Use and Future Availability	623
Artificial Recharge	627
Water Rights	627
Relationship Between Surface and Ground Water	628
SUBREGION 8, LOWER COLUMBIA	631
Hydrologic Framework	631
Climate	632
Surface Water	638
Quantity	638
Quality	665
Ground Water	669
Aquifer Units and Their Hydrologic Characteristics	670
Present Use and Future Availability	679
Artificial Recharge	680
Water Rights	680
Relationship Between Surface and Ground Water	681
SUBREGION 9, WILLAMETTE	683
Hydrologic Framework	683
Climate	684
Surface Water	691
Quantity	691
Quality	745
Ground Water	754
Aquifer Units and Their Hydrologic Characteristics	754
Present Use and Future Availability	763
Artificial Recharge	764
Water Rights	765
Relationship Between Surface and Ground Water	765
SUBREGION 10, COASTAL	769
Hydrologic Framework	769
Climate	770
Surface Water	777

CONTENTS

	Page No.
Quantity	777
Quality	847
Ground Water	855
Aquifer Units and Their Hydrologic Characteristics	855
Present Use and Future Availability	866
Artificial Recharge	867
Water Rights	868
Relationship Between Surface and Ground Water	869
SUBREGION 11, PUGET SOUND	871
Hydrologic Framework	871
Climate	873
Surface Water	879
Quantity	879
Quality	927
Ground Water	933
Aquifer Units and Their Hydrologic Characteristics	934
Present Use and Future Availability	942
Artificial Recharge	943
Water Rights	943
Relationship Between Surface and Ground Water	944
SUBREGION 12, OREGON CLOSED BASIN	947
Hydrologic Framework	947
Climate	949
Surface Water	953
Quantity	953
Quality	978
Ground Water	979
Aquifer Units and Their Hydrologic Characteristics	980
Present Use and Future Availability	987
Artificial Recharge	989
Water Rights	989
Relationship Between Surface and Ground Water	989
BIBLIOGRAPHY	993
GLOSSARY	1011

LIST OF TABLES

Table No.		Page No.
1	Water Withdrawn and Consumed for all Uses in Various Regions of the Conterminous United States, 1960	18
2	Water Use in 1965	20
3	Annual Discharge for the Columbia-North Pacific Region, 1970 Conditions, base period 1929-58	34
4	Average Discharge, in cfs, by State, 1970 Conditions	34
5	Selected Sites Where Water Data Have Been Determined	37-38
5A	Time-of-Travel Studies for Rivers at Bankful (or Higher) Stage, Columbia-North Pacific Region	49
6	Chemical Quality of Surface Waters in the United States Dissolved Solids Concentration	52
7	Recommended Drinking-Water Standards for Several Constituents and Properties of Water	53
8	Recommended Fluoride Concentrations for Drinking Water	53
9	Water Quality Tolerances for Industrial Applications	54
10	Classification of the Chemical Suitability of Water for Irrigation	54
11	Summary of Aquifer Units in the Columbia-North Pacific Region	69
12	Chart Showing Geologic Age of the Aquifer-Unit Groups and Its Relation to Hydrologic Characteristics	70
13	Summary of Storage, Recharge, and Discharge of Ground Water in Aquifer-Unit Groups in the Region	85
14	Summary of Estimated 1970 Ground-Water Withdrawal and Use	92
15	Summary of Estimated 1970 Ground-Water Withdrawal by Type of Use and Subregion	93
16	Glaciers in the Region	117
SUBREGION 1		
17	Average Monthly and Annual Precipitation	126
18	Average and Extreme Temperatures	128
19	Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More	132
20	Surface Water Rights	136
21	Streamflow Summary for Selected Sites	137
22	Discharge for Subregion	139
23-41	Monthly and Yearly Mean Discharge	142-160
42-60	Dependable Yield	181-185

LIST OF TABLES

Table No.		Page No.
61	Description of Aquifer Units and Their Hydrologic Characteristics	199
62	Storage, Recharge, and Discharge, of Ground Water in Aquifer Units	200
63	Estimated Ground-Water Withdrawal in 1970. . .	204
64	Summary of Ground-Water Rights in Washington .	207
SUBREGION 2		
65	Average Monthly and Annual Precipitation . . .	213
66	Average and Extreme Temperatures	216
67	Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More.	219
68	Surface Water Rights	222
69	Streamflow Summary for Selected Sites.	223
70	Modified Mean Discharge.	228
71-82	Monthly and Yearly Mean Discharge.	229-234
83-94	Dependable Yield	248-250
95	Dissolved Oxygen and Coliform Organisms Densities.	257
96	Description of Aquifer Units and Their Hydrologic Characteristics	266
97	Storage, Recharge, and Discharge, of Ground Water in Aquifer Units	267
98	Estimated Ground-Water Withdrawal and Use in 1970.	272
99	Summary of Ground-Water Rights	274
SUBREGION 3		
100	Average Monthly and Annual Precipitation . . .	279
101	Average and Extreme Temperatures	282
102	Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More.	284
103	Surface Water Rights	287
104	Streamflow Summary for Selected Sites.	287
105	Modified Mean Discharge for Subregion.	290
106-118	Mean Discharge	294-300
119-131	Dependable Yield	316-319
132	Dissolved Oxygen and Coliform Organisms Densities.	327
133	Description of Aquifer Units and Their Hydrologic Characteristics	335
134	Storage, Recharge, and Discharge, of Ground-Water in Aquifer Units	337
135	Estimated Ground-Water Withdrawal and Use in 1970.	341
136	Summary of Ground-Water Rights	343
SUBREGION 4		
137	Average Monthly and Annual Precipitation . . .	348

LIST OF TABLES

Table No.		Page No.
138	Average and Extreme Temperatures	350
139	Reservoirs Having a Capacity of Greater Than 5,000 Acre-Feet	355
140	Existing Wyoming Water Rights	359
140A	Existing Wyoming Surface Water Rights, 1963	361
141	Streamflow Summary for Selected Sites	361
142	Discharge in Subregion	362
143-153	Modified Mean Discharge	367-372
154-164	Dependable Yield	385-387
165	Dissolved Oxygen and Coliform Organisms Densities	393
166	Description of Aquifer Units and Their Hydrologic Characteristics	400
167	Storage, Recharge, and Discharge, of Ground Water in Aquifer Units	401
168	Estimated Ground-Water Withdrawal and Use in 1970	406
168A	Existing Nevada Ground-Water Rights	411
SUBREGION 5		
169	Average Monthly and Annual Precipitation	417
170	Average and Extreme Temperatures	420
171	Reservoirs with a Capacity Greater Than 5,000 Acre-Feet	425
171A	Existing Nevada Surface Water Rights, Subregion 5, 1969	428
172	Streamflow Summary for Selected Sites	430
173	Discharge for Subregion	430
174-185	Mean Discharge	434-439
186-197	Dependable Yield	451-453
198	Dissolved Oxygen and Coliform Organisms Densities	458
199	Description of Aquifer Units and Their Hydrologic Characteristics	465
200	Storage, Recharge, and Discharge, of Ground Water in Aquifer Units	466
201	Estimated Ground-Water Withdrawal and Use in 1970	470
202	Existing Nevada Ground-Water Rights, 1969	474
202A	Summary of Ground-Water Rights in Oregon	474
SUBREGION 6		
203	Average Monthly and Annual Precipitation	479
204	Average and Extreme Temperatures	481
205	Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More	484
206	Surface Water Rights in Washington	488
207	Streamflow Summary for Selected Sites	489
208	Discharge for Subregion	493

LIST OF TABLES

Table No.		Page No.
209-220	Observed Mean Discharge	496-401
221-232	Dependable Yield	514-516
233	Dissolved Oxygen and Coliform Organisms Densities	526
234	Description of Aquifer Units and Their Hydrologic Characteristics	532
235	Storage, Recharge, and Discharge, of Ground Water in Aquifer Units	533
236	Estimated Ground-Water Withdrawal and Use in 1970	536
237	Summary of Ground-Water Rights in Oregon	540
238	Summary of Ground-Water Rights in Washington	541
SUBREGION 7		
239	Average Monthly and Annual Precipitation	548
240	Average and Extreme Temperatures	551
241	Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More	555
242	Surface Water Rights	558
243	Streamflow Summary for Selected Sites	559
244	Discharge in Subregion	562
245-262	Mean Discharge	565-573
263-280	Dependable Yield	594-598
281	Dissolved Oxygen and Coliform Organisms Densities	610
282	Description of Aquifer Units and Their Hydrologic Characteristics	618
283	Storage, Recharge, and Discharge, of Ground Water in Aquifer Units	619
284	Estimated Ground-Water Withdrawal and Use in 1970	626
285	Summary of Ground-Water Rights in Oregon	628
286	Summary of Ground-Water Rights in Washington	628
SUBREGION 8		
287	Average Monthly and Annual Precipitation	633
288	Average and Extreme Temperatures	635
289	Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More	639
290	Surface Water Rights	641
291	Streamflow Summary for Selected Sites	642
292	Discharge in Subregion	647
293-300	Mean Discharge	648-651
301-308	Dependable Yield	660-661
309	Dissolved Oxygen and Coliform Organisms Densities	667
310	Description of Aquifer Units and Their Hydrologic Characteristics	675

LIST OF TABLES

Table No.		Page No.
311	Storage, Recharge, and Discharge, of Ground Water in Aquifer Units	677
312	Estimated Ground-Water Withdrawal and Use in 1970	678
313	Summary of Ground-Water Rights in Oregon	680
314	Summary of Ground-Water Rights in Washington	681
SUBREGION 9		
315	Average Monthly and Annual Precipitation	686
316	Average and Extreme Temperatures	689
317	Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More	692
318	Stream Diversions and Uses	693
319	Streamflow Summary for Selected Sites	695
320	Discharge in Subregion	699
321-340	Mean Discharge	703-712
341-359	Dependable Yield	732-736
360	Description of Aquifer Units and Their Hydrologic Characteristics	757
361	Storage, Recharge, and Discharge, of Ground Water in Aquifer Units	758
362	Estimated Ground-Water Withdrawal and Use in 1970	762
363	Summary of Ground-Water Rights	765
SUBREGION 10		
374	Average Monthly and Annual Precipitation	771
375	Average and Extreme Temperatures	773
376	Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More	778
377	Surface Water Rights	781
378	Streamflow Summary for Selected Sites	782
379	Discharge for Subregion	782
380-400	Mean Discharge	788-808
401-421	Dependable Yield	832-837
422	Dissolved Oxygen and Coliform Organisms Densities	851
423	Description of Aquifer Units and Their Hydrologic Characteristics (Oregon Part)	859
424	Description of Aquifer Units and Their Hydrologic Characteristics (Washington Part)	860
425	Storage, Recharge, and Discharge, of Ground Water in Aquifer Units	862
426	Estimated Ground-Water Withdrawal and Use in 1970	865
427	Summary of Ground-Water Rights, Oregon	868
428	Summary of Ground-Water Rights, Washington	868

LIST OF TABLES

Table No.		Page No.
SUBREGION 11		
429	Average Monthly and Annual Precipitation . . .	873
430	Average and Extreme Temperatures	876
431	Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More.	881
432	Water Diverted for Various Uses.	881
433	Surface Water Rights	885
434	Streamflow Summary for Selected Sites.	886
435	Discharge for Subregion.	888
436-452	Mean Discharge	892-900
453-469	Dependable Yield	919-923
470	Coliform Organisms Densities	930
471	Description of Aquifer Units and Their Hydrologic Characteristics	936
472	Storage, Recharge, and Discharge, of Ground Water in Aquifer Units	937
473	Ground-Water Withdrawal and Use in 1970. . . .	941
474	Ground-Water Rights.	944
SUBREGION 12		
475	Average Monthly and Annual Precipitation . . .	949
476	Average and Extreme Temperatures	952
477	Streamflow Summary for Selected Sites.	955
478	Monthly Discharge for Subregion.	958
479-485	Monthly and Yearly Mean Discharge.	961-964
486-492	Dependable Yield	973-974
493	Dissolved Oxygen and Coliform Organisms Densities.	979
494	Description of Aquifer Units and Their Hydrologic Characteristics	982
495	Storage, Recharge, and Discharge, of Ground Water in Aquifer Units	983
496	Estimated Ground-Water Withdrawal and Use in 1970.	988
497	Summary of Ground-Water Rights	989

LIST OF FIGURES

Figure No.		
1	Map of Region Showing Subregion Boundaries . .	5
2	Major Physiographic Features . . . . . After	6
3	Map Showing Mean Annual Precipitation in Inches	9
4	Map Showing Mean Annual Temperature, 1931-1951	10
5	Graph of Seasonal Temperatures at Seattle, Washington	11

LIST OF FIGURES

Figure No.		Page No.
6	Map Showing Length of Frost-Free Growing Season in Days	12
7	Map Showing Mean Annual Lake Evaporation in Inches, 1946-1955	14
8	Map Showing Mean Annual Runoff in Inches	After 18
8A	Watershed Area and Runoff Diagram	After 18
9	Graph of Monthly Discharge, Columbia-North Pacific Region	36
10	Graph Showing General Deviations of Precipitation in the Harney Basin as Indicated by Tree-Ring Growth, 1734-1930	42
11	Graph Showing Long-Term Variation in Precipitation and Streamflow	43
12	Summary Hydrographs	45
13	Graph Showing Time of Travel, Willamette River from Albany to Oregon City	47
14	Map Showing Flood-Wave Time of Travel	48
15	Profile of the Columbia River	50
16	Profile of the Snake River	50
17	Ranges in Water Temperature in Selected Streams	58
18	Distribution of Water Temperature, Columbia River near The Dalles, Oregon	59
19	Map Showing Areas Covered by Ground-Water Reports	64
20	Map Showing Major Ground-Water Aquifers	After 68
21	Hydrographs of Water Levels in Selected Wells	87-88
22	Hydrographs Showing Low-Flow Characteristics of Selected Streams	90
23	Flow-Duration Curves Showing Separation of Direct Runoff and Ground-Water Component of Flow	91
24	Interrelation of Ground Water and Surface Water	96
25	Runoff and Precipitation at South Cascade Glacier, Washington, 1960	116
SUBREGION 1		
26	Mean Annual Precipitation in Inches	After 126
27	Water Resource Inventory Areas	135
28	Monthly Discharge for Subregion	138
29	Map Showing Mean Annual Runoff	After 138
30-48	Mean Monthly Discharge for Selected Stations	161-165
49-67	Frequency Curves for Selected Stations	166-170
68-86	Duration Curves for Selected Stations	171-175
87-105	Frequency Curves of Annual Peak Flows for Selected Stations	176-180

LIST OF FIGURES

Figure No.		Page No.
106-108	Long-Term Variation in Precipitation and Streamflow	186-188
109-111	Profiles of Selected Streams	189-190
112	Map Showing Chemical Composition of Water	192
113	Map Showing Generalized Sediment Yield	194
114-115	Water Temperature	195
116	Map, Aquifer Units After	196
117	Map Showing General Availability of Ground Water. After	196
118	Hydrographs of Selected Wells	202
119	Hydrographs Showing Low-Flow Characteristics of Selected Streams	209
SUBREGION 2		
120	Mean Annual Precipitation in Inches	214
121	Water Resource Inventory Areas	221
122	Map Showing Mean Annual Runoff in Inches	224
123	Monthly Discharge for Subregion	225
124-135	Monthly Discharge for Selected Stations	235-237
136-147	Frequency Curves for Selected Stations	238-241
148-159	Duration Curves for Selected Stations	242-244
160-171	Frequency Curves of Annual Peak Flows for Selected Stations	245-247
172-173	Long-Term Variation in Precipitation and Streamflow	251-252
174-176	Profiles of Selected Streams	253-254
177	Map Showing Chemical Composition of Water	256
178	Map Showing Generalized Sediment Yield	259
179	Monthly Water Temperatures	260
180	Map of Aquifer Units	262
181	Map Showing General Availability of Ground Water	263
182	Hydrographs of Selected Wells	269
183	Hydrographs of Low-Flow Characteristics of Selected Streams	270
SUBREGION 3		
184	Mean Annual Precipitation in Inches	280
185	Water Resource Inventory Areas	286
186	Map Showing Mean Annual Runoff in Inches	288
187	Monthly Discharge for Subregion	289
188-200	Monthly Discharge for Selected Stations	301-304
201-213	Frequency Curves for Selected Stations	304-308
214-226	Duration Curves for Selected Stations	309-312
227-239	Frequency Curves of Annual Peak Flows for Selected Stations	313-315
240-241	Long-term Variation in Precipitation and Streamflow	320-221

LIST OF FIGURES

Figure No.		Page No.
242	Travel Time of Selected Streams	322
243-244	Profiles of Selected Streams	322-323
245	Map Showing Chemical Composition of Water	325
246	Dissolved Oxygen Percent Saturation	326
247	Coliform Bacteria Densities	328
248	Map Showing Generalized Sediment Yield	329
249	Monthly Water Temperatures	330
250	Map Aquifer Units	332
251	Map Showing General Availability of Ground Water	336
252	Hydrographs of Selected Wells	340
253	Hydrographs of Low-Flow Characteristics of Selected Streams	344
SUBREGION 4		
254	Mean Annual Precipitation in Inches	347
255	Uncommitted Water Passing Milner Dam	358
256	Map Showing Mean Annual Runoff in Inches	364
257	Monthly Discharge for Subregion	366
258-268	Monthly Discharge for Selected Stations	373-375
269-279	Frequency Curves for Selected Stations	376-379
280-290	Duration Curves for Selected Stations	379-382
291-297	Frequency Curves of Annual Peak Flows for Selected Stations	382-384
298	Long-Term Variation in Precipitation and Streamflow	388
299	Travel Time of Selected Streams	389
300	Profiles of Selected Streams	390
301	Map Showing Chemical Composition of Water	392
301A	Map Showing Generalized Sediment Yield	395
302	Monthly Water Temperatures	396
303	Map Aquifer Units	After 400
304	General Availability of Ground Water	After 400
305	Hydrographs of Selected Wells	404
306	Hydrographs of Low-Flow Characteristics of Selected Streams	405
SUBREGION 5		
307	Mean Annual Precipitation in Inches	418
308	Map Showing Mean Annual Runoff in Inches	429
309	Monthly Discharge for Subregion	433
310-321	Monthly Discharge for Selected Stations	440-442
322-333	Frequency Curves for Selected Stations	443-446
334-345	Duration Curves for Selected Stations	447-449
346-349	Frequency Curves of Annual Peak Flows for Selected Stations	450
350	Long-Term Variation in Precipitation and Streamflow	454

LIST OF FIGURES

Figure No.		Page No.
351	Profiles of Selected Streams	455
352	Map Showing Chemical Composition of Water.	457
353	Map Showing Generalized Sediment Yield	460
354	Monthly Water Temperatures	461
355	Map Aquifer Units.	After 462
356	Map Showing General Availability of Ground Water and Depth to Water Level	After 464
357	Hydrographs of Selected Wells.	468
358	Hydrographs of Low-Flow Characteristics of Selected Streams	475
SUBREGION 6		
359	Mean Annual Precipitation in Inches.	After 480
360	Water Resource Inventory Areas	487
361	Monthly Discharge for Subregion.	490
362	Map Showing Mean Annual Runoff in Inches	491
363-374	Monthly Discharge for Selected Stations.	502-504
375-386	Frequency Curves for Selected Stations	505-507
387-398	Duration Curves for Selected Stations.	508-510
399-410	Frequency Curves of Annual Peak Flows for Selected Stations.	511-513
411-413	Long-Term Variation in Precipitation and Streamflow	517-519
414-415	Travel Time of Selected Streams.	520-521
416	Profiles of Selected Streams	522
417	Map Showing Chemical Composition of Water.	524
418	Map Showing Generalized Sediment Yield	527
419-420	Monthly Water Temperatures	529
421	Map Aquifer Units.	After 530
422	Map Showing General Availability of Ground Water	After 530
423	Hydrographs of Selected Wells.	539
424	Hydrographs of Low-Flow Characteristics of Selected Streams	543
SUBREGION 7		
425	Mean Annual Precipitation in Inches.	549
426	Water Resource Inventory Areas	557
427	Monthly Discharge for Subregion.	560
428	Map Showing Mean Annual Runoff in Inches	561
429-446	Monthly Discharge for Selected Stations.	574-578
447-464	Frequency Curves for Selected Stations	579-583
465-482	Duration Curves for Selected Stations.	584-588
483-499	Frequency Curves of Annual Peak Flows for Selected Stations.	589-593
500-504	Long-Term Variation in Precipitation and Streamflow	599-603
505-506	Travel Time of Selected Streams.	604-605

LIST OF FIGURES

Figure No.		Page No.
507-509	Profiles of Selected Streams	606-607
510	Map Showing Chemical Composition of Water.	609
511	Map Showing Generalized Sediment Yield	612
512-515	Monthly Water Temperatures	613-614
516	Map Aquifer Units.	After 618
517	Map Showing General Availability of Ground Water.	After 618
518	Hydrographs of Selected Wells.	622
519	Hydrographs of Low-Flow Characteristics of Selected Streams	624
SUBREGION 8		
520	Mean Annual Precipitation in Inches.	636
521	Map Water Resource Inventory Area.	641
522	Monthly Discharge for Subregion.	645
523	Map Showing Mean Annual Runoff in Inches	646
524-531	Monthly Discharge for Selected Stations.	652-653
532-539	Frequency Curves for Selected Stations	654-655
540-547	Duration Curves for Selected Stations.	656-657
548-553	Frequency Curves for Annual Peak Flows for Selected Stations.	658-659
554-555	Long-Term Variation in Precipitation and Streamflow	662-663
556-557	Profiles of Selected Streams	664
558	Map Showing Chemical Composition of Water.	666
559	Map Showing Generalized Sediment Yield	668
560	Map Aquifer Units.	671
561	Map Showing General Availability of Ground Water.	673
562	Hydrographs of Selected Wells.	676
563	Hydrographs Showing Low-Flow Characteristics of Selected Streams	682
SUBREGION 9		
564	Mean Annual Precipitation in Inches.	687
565	Water Resource Inventory Areas	696
566	Monthly Discharge for Subregion.	697
567	Map Showing Mean Annual Runoff in Inches	698
568-586	Monthly Discharge for Selected Stations.	713-717
587-605	Frequency Curves for Selected Stations	718-722
606-624	Duration Curves for Selected Stations.	723-727
625-640	Frequency Curves of Annual Peak Flows of Selected Stations.	728-731
641-643	Long-Term Variation in Precipitation and Streamflow	737-739
644-649	Travel Time of Selected Streams.	740-742
650-653	Profiles of Selected Streams	743-744
654	Map Showing Chemical Composition of Water.	746

LIST OF FIGURES

Figure No.		Page No.
655	Dissolved Oxygen Percent Saturation	749
656	Coliform Bacteria Densities	749
657	Map Showing Generalized Sediment Yield.	751
658-660	Monthly Water Temperatures.	After 753-754
661	Map Aquifer Units	758
662	Map Showing General Availability of Ground Water	After 758
663	Hydrographs of Selected Wells	761
664	Hydrographs of Low-Flow Characteristics of Selected Streams.	767
SUBREGION 10		
665	Mean Annual Precipitation in Inches	After 772
666	Water Resource Inventory Areas.	780
667	Monthly Discharge for Subregion	783
668	Map Showing Mean Annual Runoff in Inches.	784
669-689	Monthly Discharge for Selected Stations	809-814
690-710	Frequency Curves for Selected Stations.	814-820
711-731	Duration Curves for Selected Stations	821-826
732-750	Frequency Curves of Annual Peak Flows for Selected Stations	826-831
751-753	Long-Term Variation in Precipitation and Streamflow.	838-840
754-756	Travel Time of Selected Streams	841-842
757-764	Profiles of Selected Streams.	843-846
765	Map Showing Chemical Composition of Water	848
766	Map Showing Generalized Sediment Yield.	852
767-770	Monthly Water Temperatures.	853-854
771	Map Aquifer Units	After 856
772	Map Showing General Availability of Ground Water	After 856
773	Hydrographs of Selected Wells	864
774	Hydrographs of Low-Flow Characteristics of Selected Streams.	870
SUBREGION 11		
775	Mean Annual Precipitation in Inches	874
776	Water Resource Inventory Areas.	884
777	Monthly Discharge for Subregion	887
778	Map Showing Mean Annual Runoff in Inches.	889
779-795	Monthly Discharge for Selected Stations	901-905
796-812	Frequency Curves for Selected Stations.	905-909
813-829	Duration Curves for Selected Stations	910-914
830-846	Frequency Curves of Annual Peak Flows for Selected Stations	914-918
847	Long-Term Variation in Precipitation and Streamflow.	924
848-849	Travel Time of Selected Streams	925

LIST OF FIGURES

Figure No.		Page No.
850-852	Profiles of Selected Streams.	926-927
853	Map Showing Chemical Composition of Water . . .	928
854	Map Showing Generalized Sediment Yield.	932
855	Monthly Water Temperatures.	933
856	Map Aquifer Units . . . . . After	934
857	Map Showing General Availability of Ground Water . . . . . After	934
858	Hydrographs of Selected Wells	939
859	Hydrographs of Low-Flow Characteristics of Selected Streams.	946
SUBREGION 12		
860	Mean Annual Precipitation in Inches	950
861	Water Resource Inventory Areas.	955
862	Map Showing Mean Annual Runoff in Inches. . . .	956
863	Monthly Discharge for Subregion	957
864-870	Monthly Discharge for Selected Stations	965-966
871-877	Frequency Curves for Selected Stations.	967-968
878-884	Duration Curves for Selected Stations	969-970
885-890	Frequency Curves of Annual Peak Flows for Selected Stations	971-972
891-892	Long-Term Variation in Precipitation and Streamflow.	975-976
893	Profiles of Selected Streams.	977
894	Map Aquifer Units . . . . . After	980
895	Map Showing General Availability of Ground Water and Depth to Water Level. . . . . After	982
896	Hydrographs of Selected Wells	985
897	Hydrographs of Low-Flow Characteristics of Selected Streams.	990

I N T R O D U C T I O N

PURPOSE AND SCOPE

Purpose

The purpose of this appendix is to assemble available water resources data in a summarized form to provide information, not only for the agencies dealing with the management of the water resources of the region, but also for those planning the economic development which is dependent upon those resources. Much information about the water resources of the Columbia-North Pacific Region is available but it differs widely in character, scope, and geographic coverage and must be obtained from many sources. Information also is available on various water laws, technological developments, and economic and population trends that will influence the availability of and requirements for water in the future.

The goal of water conservation is the management of this renewable natural resource to provide the optimum benefits from use of the water, now and in the future. To achieve this goal, intelligent planning and orderly development are needed. Proper planning and development require adequate information about the water resource and how man's activities have affected and are likely to affect it.

Scope

The study consists primarily of summarization, analysis, and extension of existing data on water resources of the region. Essentially data used were taken from published sources. Some river discharges were obtained by computer analysis of observed information. The base period selected is 1929-58. The discharges used throughout generally reflect 1970 or 1975 conditions of development; that is, the natural flows have been depleted and regulated for those anticipated levels of use.

Detailed data are presented for each of the 12 subregions. They include information on the quantity and quality of both surface and ground water. The total quantity of water available in each subregion is shown by month on graphs and in tables. Water records for selected streams were analyzed and summarized as: (1) mean monthly discharge for several conditions of flow: maximum, minimum, mean, 20- and 80-percent frequencies of occurrence, and

maximum and minimum years; (2) peak discharge frequency; (3) high-flow and low-flow discharge frequency for preselected periods of 1 to 12 months; (4) duration curves of monthly and annual flows; (5) lowest mean flows for 1 to 10 consecutive years in the 30-year base period; and (6) seasonal and annual variations in water discharge. Also included are data on water quality: chemical, biological-biochemical, sediment, and temperature. The availability, distribution, and quality of ground water are presented in maps and tables.

Each subregion report also contains a general hydrologic description of the area; a fairly detailed description of the climate; and discussions of water use, stream management, and water rights. In addition, the Regional Summary includes sections covering technological advancements and areas of need for additional hydrologic data.

Definition of Present Conditions

In order to determine monthly mean regulated flows at various locations on streams in the Columbia-North Pacific Region, a definition of "present conditions" is needed.

Modified flow representing present conditions for the Columbia River and certain principal tributaries reflect irrigation depletions as of 1970, power and flood control regulation by reservoirs existing or under construction in 1970. Present conditions for the remaining upstream tributaries are those of the existing depletion studies adjusted for the amount of land under irrigation in 1966.

The modified flows previously determined by the Columbia Basin Inter-Agency Committee are historical flows for the base period 1929-58 that were modified by estimated depletions for 1960 and 2010 conditions of irrigation development and by adjustments for changes in contents of reservoirs and natural lakes. This placed all streamflows for the 30-year base period on a comparable-use basis.

Existing projects are known. Those under construction, or assumed to be under construction by 1970 for purposes of the study (including licensed or authorized) follow:

Project	Stream	Subregion
Mica	Columbia River	In Canada
Libby	Kootenai River	1
Teton	Teton River	4
Asotin	Snake River	6

Dworshak	N. F. Clearwater River	6
Lower Granite	Snake River	6
Little Goose	Snake River	6
Lower Monumental	Snake River	6
Lost Creek	Rogue River	10

Additional generation units are authorized for the following projects which were considered as under construction:

Project	Stream	Subregion
Boundary	Pend Oreille River	1
Grand Coulee	Columbia River	2
Chief Joseph	Columbia River	2
Wells	Columbia River	2
Rocky Reach	Columbia River	2
Hells Canyon	Snake River	6
Ice Harbor	Snake River	6
John Day	Columbia River	7
The Dalles	Columbia River	7
Bonneville	Columbia River	7

RELATIONSHIP TO OTHER PARTS OF REPORT

Appendix V, Water Resources, is one of three basic data appendices used in preparing the functional appendices, the comprehensive framework plan, and the Main Report. The other two basic data appendices are Land and Mineral Resources and Economic Base and Projections. The Water Resources Appendix furnishes data on the quantity and quality of both surface water and ground water for use in defining present conditions with respect to water availability for the functional appendices. The projections of future water use developed in the nine functional appendices will be used in conjunction with the Water Resources data to determine excesses and deficiencies of water when considering the many alternatives for water development in the plan formulation phase. Appendix V also was used in presenting the present water situation for the Main Report; as well as to show needs for additional data and possible technological advances that may in the future enhance the water resources of the region.

DESCRIPTION OF THE REGION

The Columbia-North Pacific Region includes all of the Columbia River drainage in the United States, the coastal streams of Oregon and Washington, and the Closed Basin in south-central Oregon. This area of approximately 274,400 square miles (271,430 sq. mi of land and 2,984 sq. mi. of water) encompasses all the

State of Washington, most of Idaho and Oregon, and parts of Montana, Nevada, Utah, and Wyoming. The region is bounded on the east by the Rocky Mountains, on the north by the Canadian border, on the west by the Pacific Ocean, and on the south generally by the California and Nevada state lines and the Snake River drainage divide. The regional and subregional boundaries are shown in figure 1. The major physiographic features are shown in figure 2.

The Olympic Mountains in the northwest corner of the region are steep and rugged. Many foothills rise to altitudes of 4,500 to 5,000 feet to create a gently undulating horizon. Above this horizon rise exceedingly sharp ridges and crags, many of them to altitudes of 7,000 and 8,000 feet, with Mount Olympus reaching 8,200 feet. Most of the drainage is by small rivers running westward to the Pacific Ocean or eastward to Puget Sound. These mountains cause extremely high precipitation and create the wettest spot in the conterminous United States, where at higher altitudes in certain areas average annual rainfall is as great as 240 inches. The Coast Range, which includes the Olympic Mountains, extends southward through Washington and Oregon, with generally rough terrain although not as high as the Olympic Mountains. Drainage is mostly by small rivers running to the Pacific Ocean and by the Willamette River system which carries considerable quantities of water from precipitation averaging 100 inches or more per year in the higher mountains.

The Willamette-Puget Sound Trough extends from the Canadian border through Puget Sound and the Willamette Basin. The trough is 30 to 50 miles wide, about 350 miles long, lies mostly below an altitude of 500 feet, receives an average of about 40 inches of precipitation each year, and is underlain by alluvial and glacial rock materials.

The Cascade Range divides the region into two distinct parts--the generally wet west side with moderate temperatures, and the more arid east side with its greater extremes in weather. Most of the mountains range in altitude from 5,000 to 8,000 feet with several volcanic peaks exceeding 10,000 feet, the highest being Mount Rainier at 14,410 feet. The streams have fairly steep gradients and drainage is chiefly to the Willamette River and Puget Sound on the west side and to the Columbia Basin on the east. In fact, all drainage east of the Cascade Range is to the Columbia Basin.

The Columbia Plateau-Blue Mountains-Snake River Plateau area occupies nearly 40 percent of the region and lies at an average elevation of about 3,500 feet. Precipitation is generally scanty ranging from about 10 inches annually over large areas to 50 to 80 inches on isolated mountains. Stream gradients are relatively gentle. About 60 percent of the area drains to the Snake River, the major Columbia River tributary, about 10 percent to the Oregon



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

THE REGION
1968

FIGURE 1

Closed Basin, and the remainder to the Columbia River and its other tributaries.

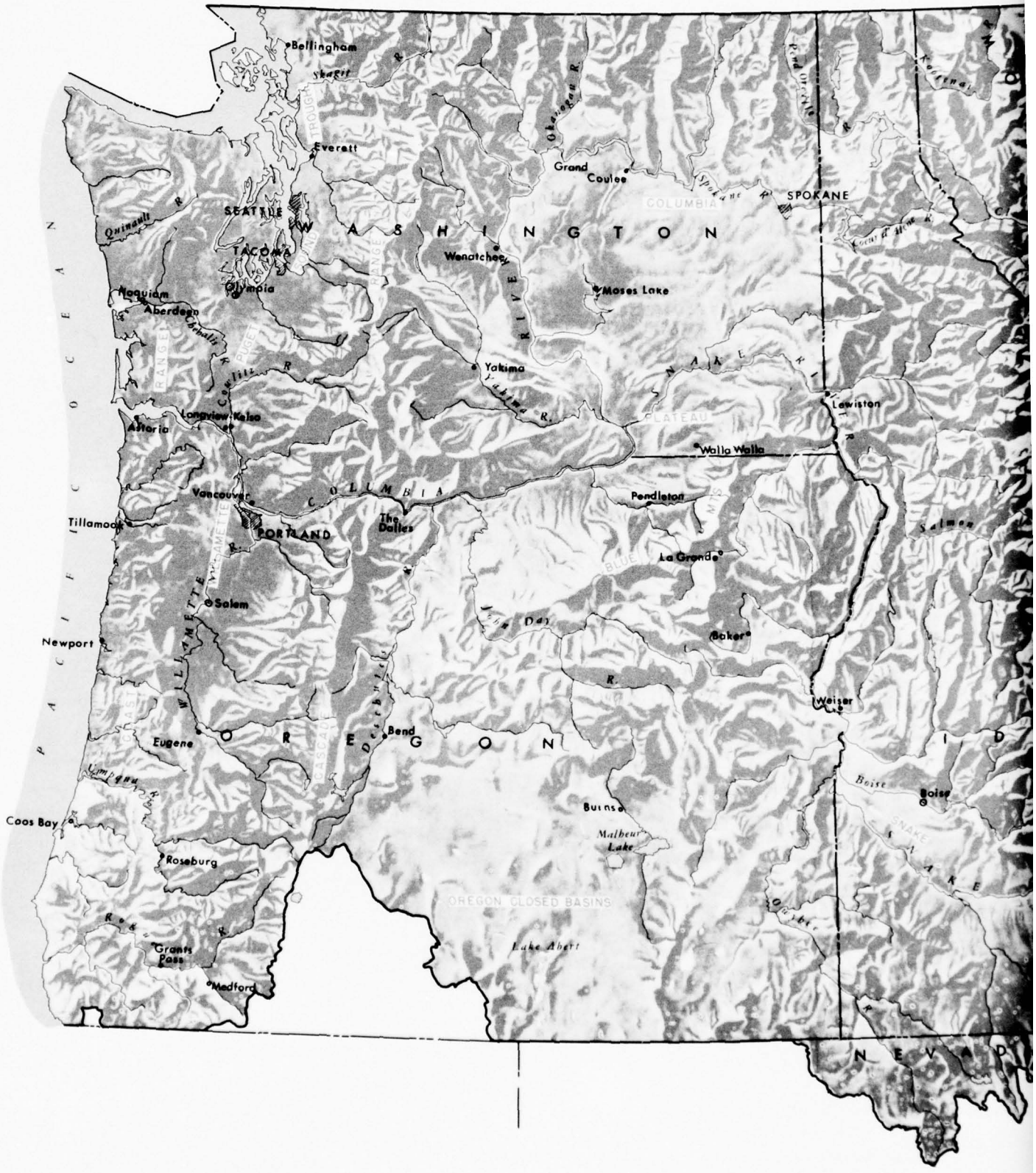
More than 30 percent of the region lies in the area designated physiographically as the Northern Rocky Mountains. Western Montana, much of Idaho, and the northeast corner of Washington lie in this area which comprises numerous mountain ranges separated by narrow valleys through which flow the major streams. Stream gradients are steep as the altitudes range from 2,000 feet in the lowest valleys to more than 10,000 feet on many of the peaks. The southern part is drained into the Columbia River by the Snake River and the northern part drains to the Columbia River through the Kootenai, Clark Fork, and Spokane Rivers. Annual precipitation ranges from 10 to 60 inches.

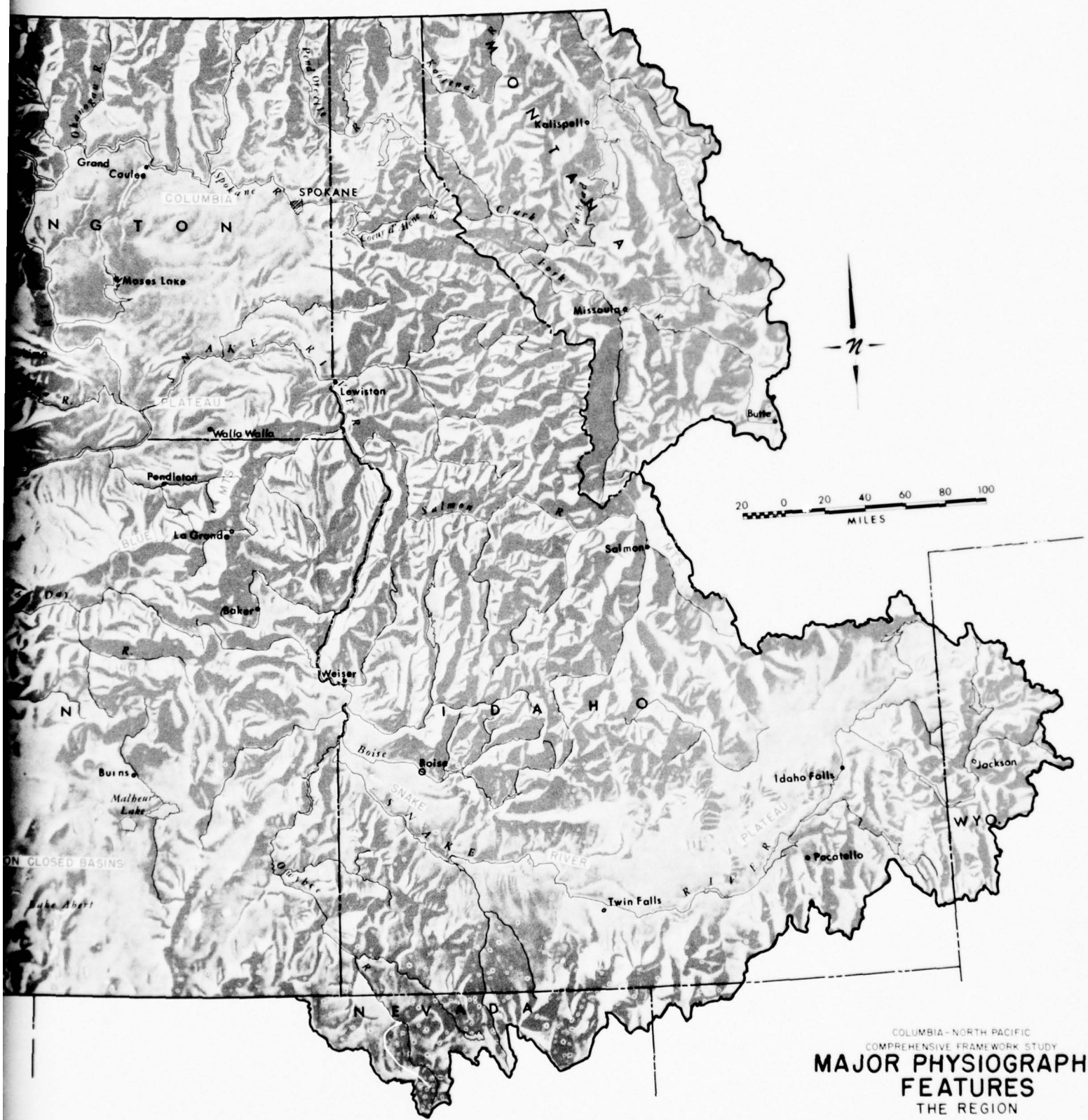
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The analyses of field data and report preparation were carried out by the Corps of Engineers in Portland, Oregon, Seattle and Walla Walla, Washington; the Bureau of Reclamation in Boise, Idaho, Spokane, Washington, and Salem, Oregon; and the Geological Survey, in Portland, Oregon. Mr. Harold D. Hafterson coordinated the work of the Bureau of Reclamation in the preparation of five subregion reports. Mr. John Summersett coordinated the work of the Corps of Engineers, wrote the computer programs, and participated in the preparation of six subregion reports. Mr. George L. Bodhaine of the Geological Survey prepared one subregion report, furnished the information on chemical quality of water and sediment for all the subregion reports, prepared a large part of the Regional Summary, and, as Chairman of the Hydrology Work Group, provided general guidance during report preparation. Mr. Maurice J. Mundorff, Geological Survey, provided all the ground-water information for the region. The several state climatologists furnished the sections on climatological data. Data on Water Rights were furnished by the individual state representatives: A. C. Robertson, Idaho; A. J. Mancini, Montana; E. J. DeRicco, Nevada; C. L. Rempel, Oregon; E. B. Haycock, Utah; M. E. Garling, Washington; and F. A. Bishop, Wyoming.

The principal sources of water data were the Geological Survey Water-Supply Papers, the depletion and modified-flow studies of the Columbia Basin Inter-Agency Committee, recent irrigation depletion studies for the upper and central Snake River basin by the Bureau of Reclamation, and computer study 75-8 of flows modified for an anticipated 1975 level of irrigation depletion, and storage and regulation for flood control and power production by Bonneville Power Administration.

Acknowledgment is also made to the many other individuals and agencies who furnished assistance and data for this report.


Bellingham
Skagit R.
Everett
SEATTLE
TACOMA
Olympia
Aberdeen
Quinault R.
Chehalis R.
Cowlitz R.
Longview-Kelso
Astoria
Tillamook
Vancouver
PORTLAND
Columbia R.
The Dalles
Willamette R.
Salem
Newport
Eugene
Coos Bay
Umpqua R.
Roseburg
Rogue R.
Grants Pass
Medford
Cascade Range
Deschutes R.
Bend
Puget Trough
Coast Range
Okanogan R.
Grand Coulee
Wenatchee
Yakima
Yakima R.
Moses Lake
Columbia Plateau
Spokane R.
SPOKANE
Pend Oreille R.
Kootenai R.
Lewiston
Walla Walla
Pendleton
La Grande
John Day R.
Baker
Weiser
Boise
Boise R.
Snake R. Plain
Burns
Malheur Lake
OREGON CLOSED BASINS
Lake Abert
Owyhee R.
Salmon
Blue Mts.
WASHINGTON
OREGON
IDAHO
NEVADA
PACIFIC OCEAN



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MAJOR PHYSIOGRAPHIC FEATURES
THE REGION

1968

FIGURE 2

REGIONAL SUMMARY

CLIMATE

The climate of the Columbia-North Pacific Region is associated with the southerly and easterly drift of cyclonic storms that develop in the northern Pacific Ocean, and with the seasonal migration of the semipermanent high-pressure anticyclonic area of the central Pacific. In winter, the storms pass over the region causing most of it to have distinctly wet winters. Because the storms swing farther north in summer, most of the region has relatively dry summers; however, in the interior, continental airmasses bring summer rains. The general eastward movement of marine air over the area keeps temperatures moderate most of the time. Occasionally, however, continental high-pressure areas reverse the general flow, and dry air--hot in summer and cold in winter--moves westward rather than eastward.

Detailed information on the various climatological factors are presented in the subregion reports. Generalized data are presented here in summary form, mostly on maps, to provide for easy comparison between subregions and to show the overall situation.

Weather Records

There are about 560 stations in the Columbia-North Pacific Region where precipitation and temperature data are collected regularly. Evaporation and wind data are collected at about 40 sites. Fair coverage of the region is obtained at lower elevations, but there are only a few stations at the higher elevations, and in areas where orographic features cause sudden changes in weather. In the more inaccessible areas, precipitation rates are inferred from river discharge and other factors.

The Meteorology Committee of the Pacific Northwest River Basins Commission recently prepared a Climatological Handbook for the region. This handbook is available for general use and contains information on many kinds of climatological data, including summaries of various statistical parameters as well as the usual monthly and annual summaries.

Weather data for about 10 to 15 selected sites are included in each of the subregion reports. These data generally are for representative stations that show the range in climatic conditions existing in the lowlands of the subregion.

Precipitation

Generalized mean annual precipitation is shown in figure 3. The map shows that 27 percent of the area receives less than 12 inches of precipitation and that less than 1 percent of the area receives more than 120 inches. The highest precipitation areas lie in or west of the Cascade Range. Precipitation ranges from a low of less than 10 inches in some part of each of the states, to a high of 240 inches in the Olympic Mountains in Washington. Surprisingly, though, one of the driest areas, Sequim, Washington, with about 15 inches of annual precipitation, lies in the rain shadow of the Olympic Mountains, only 30 miles from the wettest spot. The greatest single-season snowfall ever recorded in the United States was 1,000 inches at Paradise Ranger Station on Mount Rainier during the winter of 1955-56.

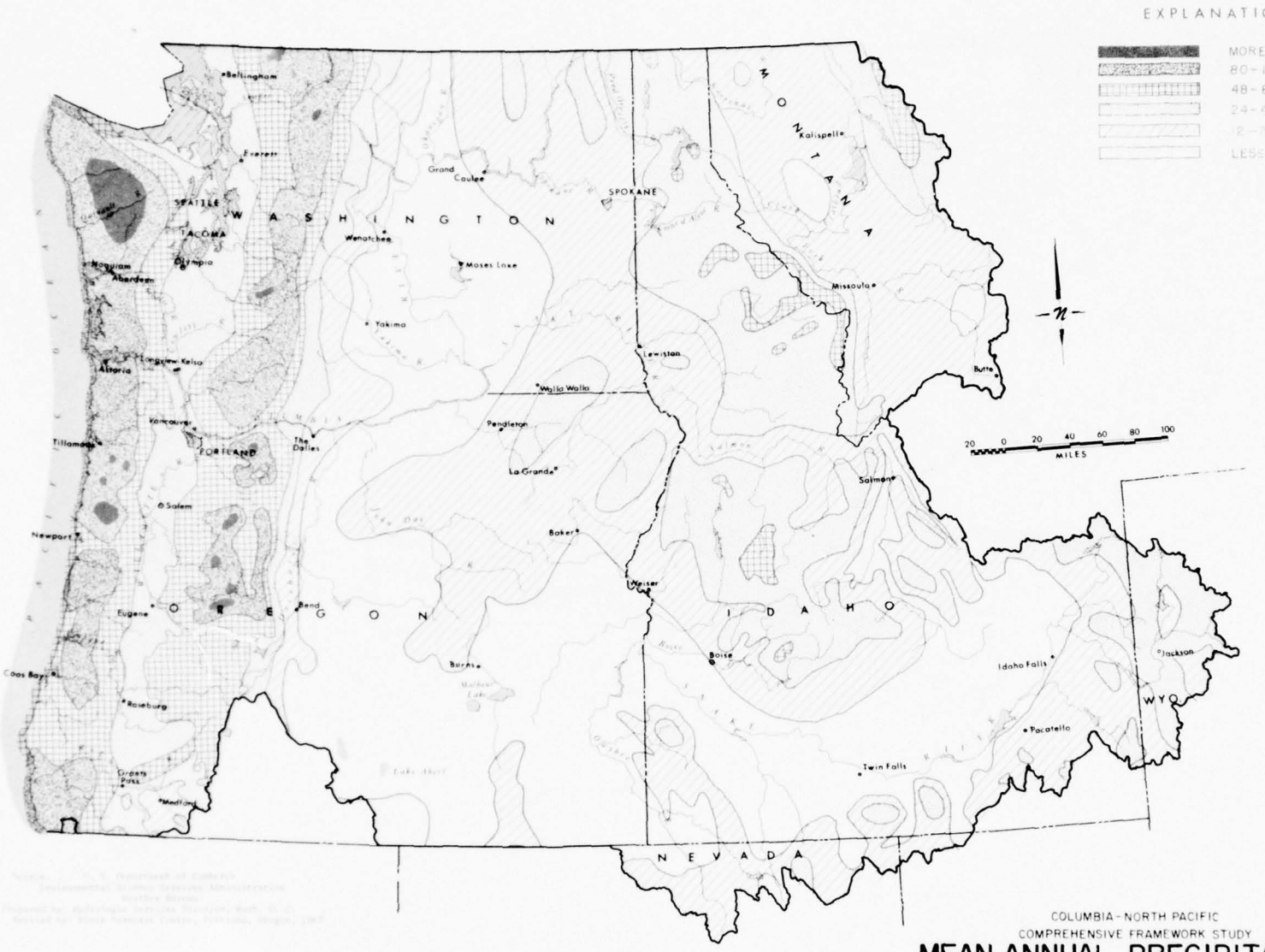
Mean monthly and mean annual precipitation are shown in the subregion reports for selected sites that represent typical areas and elevations in the subregion. The 30-year normal period referred to in the subregion reports is the climatological standard normal based on the period 1931-60.

Temperature

Mean annual temperature is shown on the map, figure 4. This generalized map does not show extremes and does not indicate the mildness of the climate west of the Cascade Range as compared with that east of the Cascade Range. Detailed data in the subregion reports show average maximum, average minimum, mean, highest, and lowest temperatures at selected sites that are representative of various climatic areas in the subregion.

A graph of average seasonal temperatures at Seattle, Washington, is presented in figure 5, which shows the year-to-year range in average seasonal temperatures encountered, even in the mild west coast climate. The highest temperature recorded in the region was 119° F. at Prineville in central Oregon on July 29, 1898, and the lowest temperature was -70° F. at Rogers Pass, on the Continental Divide, near Lincoln, Montana, on January 20, 1954. Incidentally, this is the lowest temperature ever recorded in the United States, excluding Alaska.

Air temperatures in relation to the length of the frost-free growing season are shown in figure 6. The range in frost-free days is from more than 240 days along the Pacific Ocean to less than 40 days in some areas along the Continental Divide in eastern Idaho. About 60 percent of the region lies in the middle classes of frost-free days, 80 to 120 and 120 to 160 days, with about 32 percent in the 80- to 120-day range.



COLUMBIA-NORTH PACIFIC
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MEAN ANNUAL PRECIPITATION IN INCHES THE REGION

1968

FIGURE 3



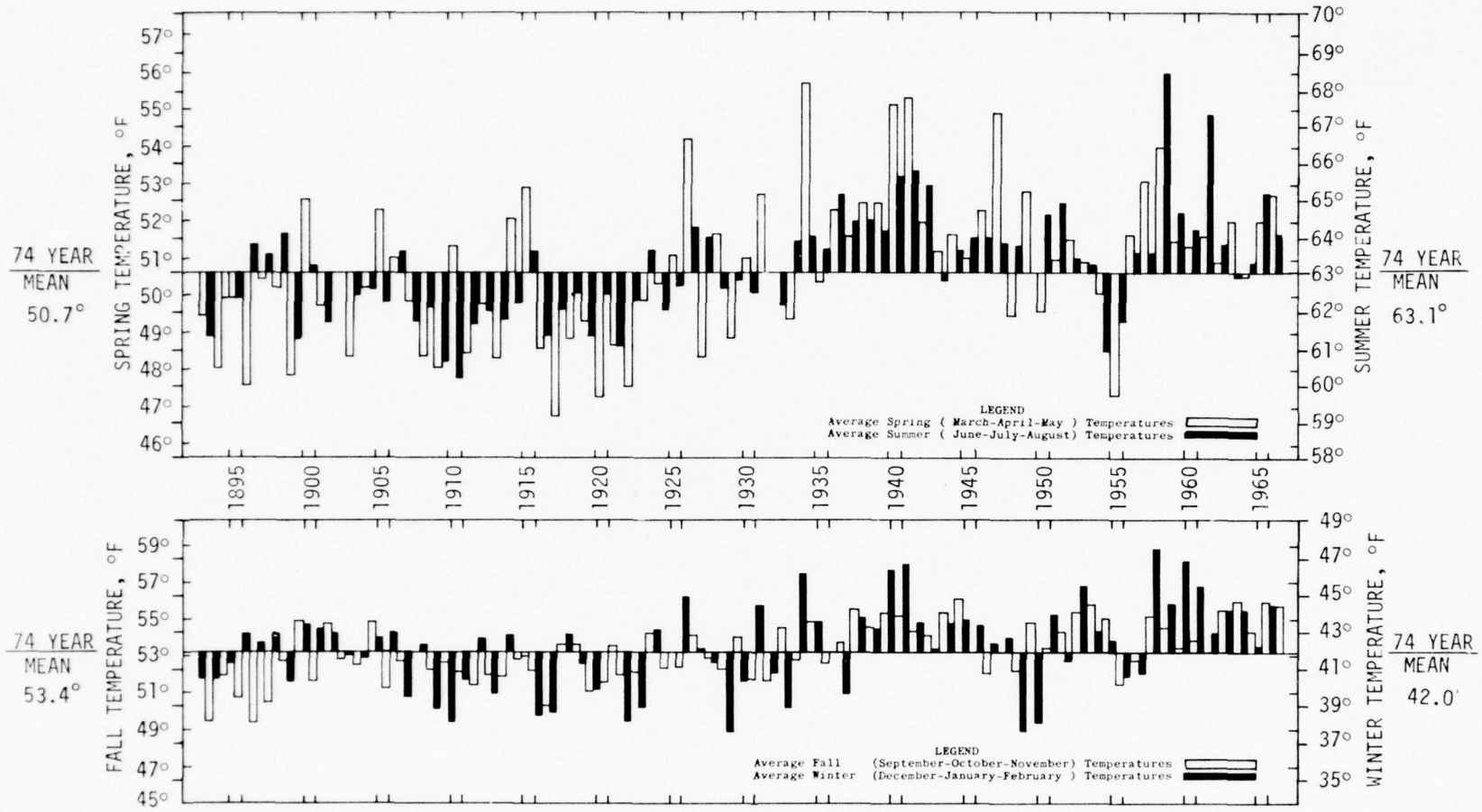
COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL TEMPERATURES 1931 – 1951

THE REGION

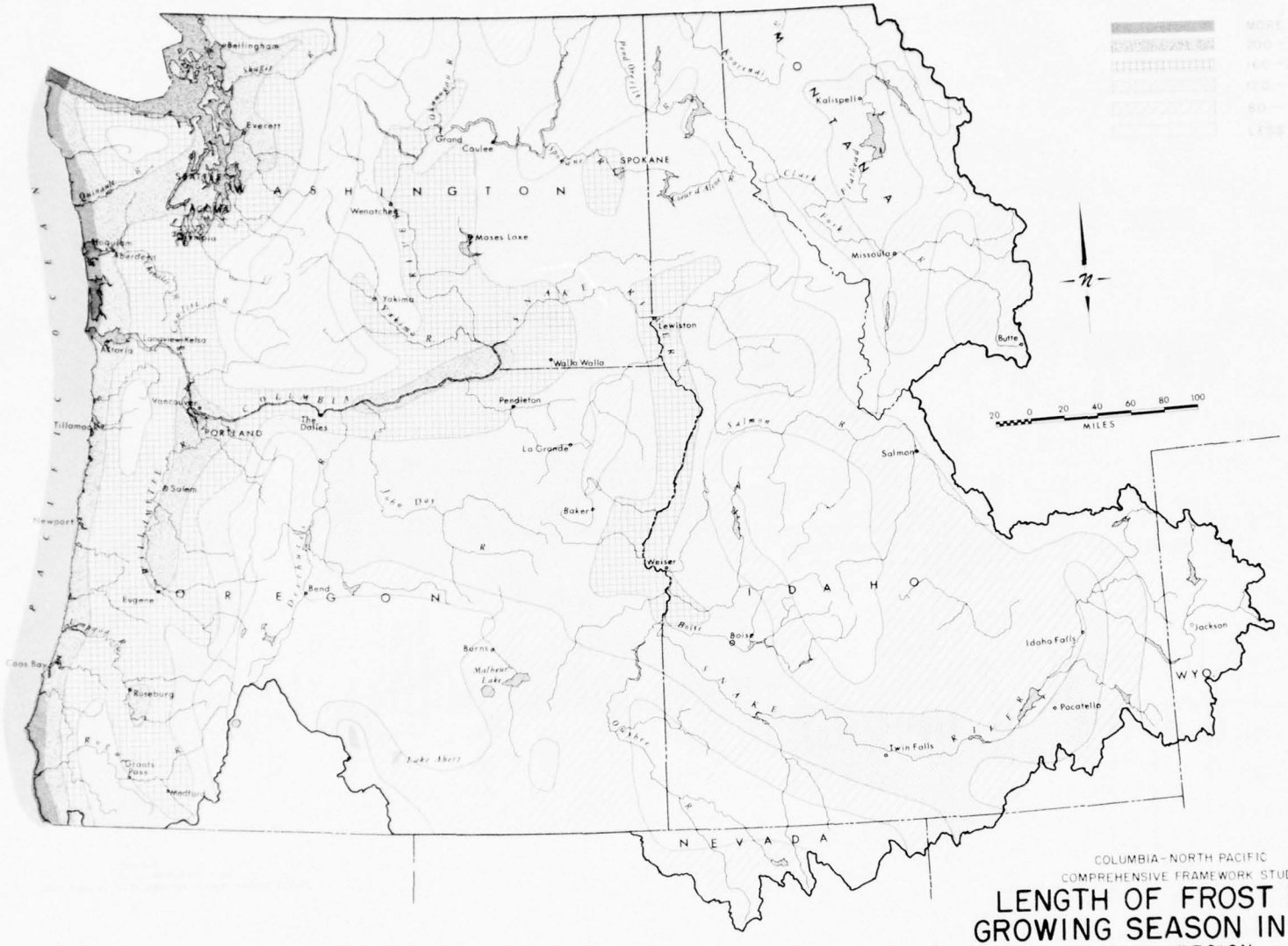
1968

FIGURE 4



Where value for a season is not shown, the average for that season was within 0.5° of the 74 year mean.

FIGURE 5. Seasonal Temperatures at Seattle, Washington



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

LENGTH OF FROST FREE GROWING SEASON IN DAYS

THE REGION

1968

FIGURE 6

Wind

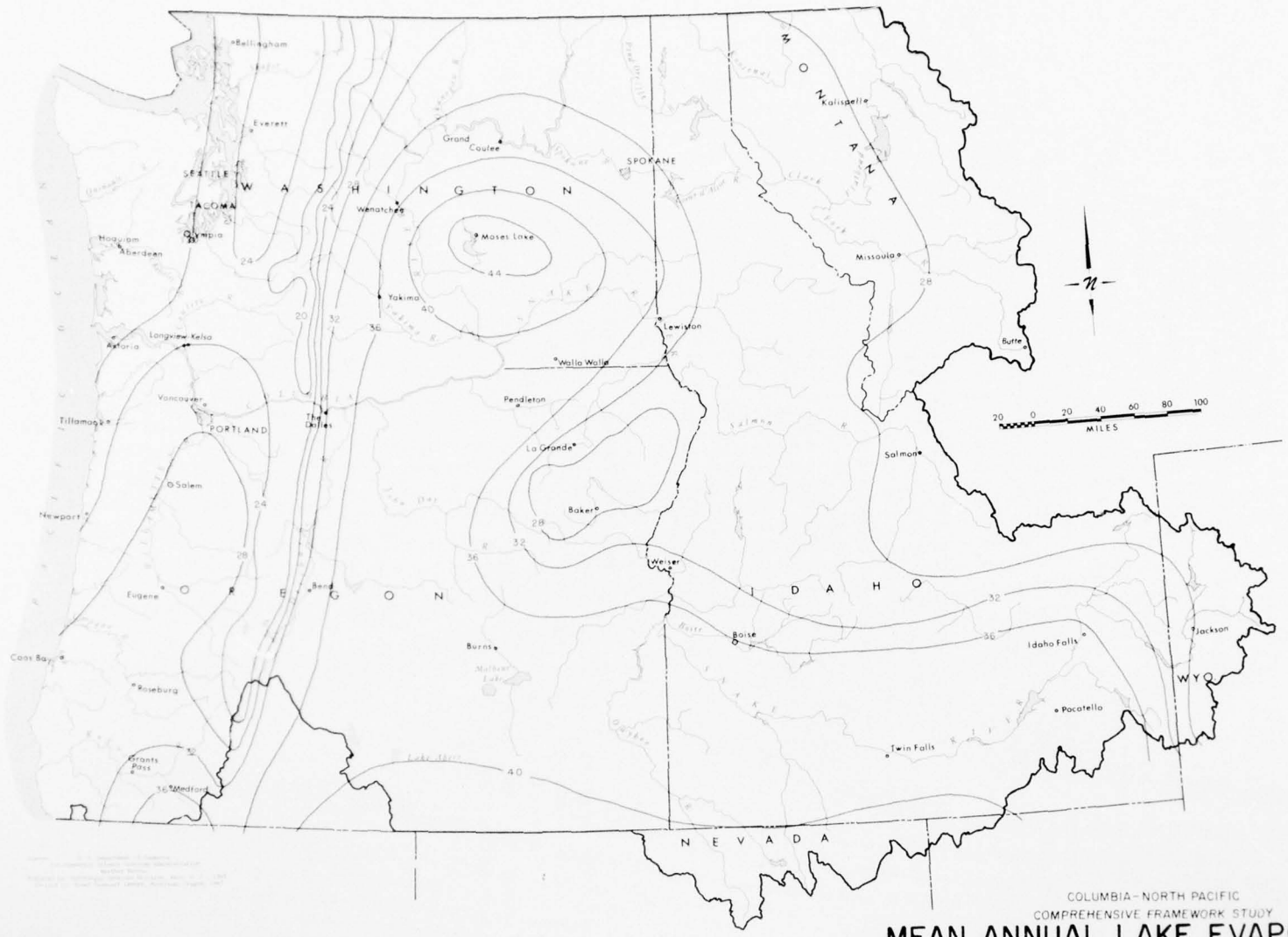
Windstorms along the Pacific Ocean shoreline in Subregion 10 occasionally reach hurricane force and do considerable damage. Wind speeds exceeding 100 mph have been recorded all along the coast. Such high winds normally do not occur in the Puget Sound and Willamette Subregions, although occasionally damaging storms occur during the winter. However, the most spectacular windstorm occurred on Columbus Day in 1962 when a gust of 116 mph was recorded in Portland, Oregon. Cold winds from the north and east often bring freezing weather during mid-winter, and warm winds from the south and southwest usually accompany fall and winter rains and snowstorms. Average wind velocity ranges from 4 to 16 mph with little change from month to month.

East of the Cascade Range prevailing winds are westerly. Greatest wind movement occurs in spring, but the winds generally are light, averaging from 2 to 5 mph. Severe winds occur along the Columbia River and dust storms are common during the drier months throughout the arid part of the region. In the Snake River Plain and in the Northern Rocky Mountains high winds up to 60 mph sometimes occur for short periods; however, average wind velocity in the valley areas is from 6 to 8 mph.

Evaporation

The evaporation averages presented in the climatological sections of this study were obtained from Class A evaporation pan records. Various studies have shown lake (free water) evaporation to vary from about 60 to 81 percent of pan evaporation. Evaporation is strongly affected by wind, humidity, and temperature. It is a major cause of loss of water, especially locally where there are large exposed water surfaces. In 1954 about 2,600,000 acre-feet of water evaporated from the principal reservoirs and regulated lakes, and about 390,000 acre-feet evaporated from other large fresh-water lakes in the region. The total is the equivalent of a stream flowing 4,200 cfs (cubic feet per second) throughout the year. In addition, about 770,000 acre-feet evaporated from the generally saline lakes located in Subregion 12. Projections to 1970 indicate that 3,900,000 acre-feet will then be evaporated annually from principal reservoirs and regulated lakes, an increase of 50 percent since 1954. The total annual evaporation from the above three sources is projected to be about 5,060,000 acre-feet, the equivalent of a stream flowing 7,000 cfs, or the average summer flow of Willamette River at Oregon City. As reservoir construction continues, evaporation losses will increase.

Average annual lake evaporation, in inches, throughout the region is shown in figure 7. The highest rate of evaporation, which



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL LAKE EVAPORATION IN INCHES, 1946 - 1955
THE REGION
1968

FIGURE 7

occurs in central Washington near Ephrata, is 44 inches per year. Average monthly evaporation in the region in percentage of total annual ranges from about 1 percent in December to 19 percent in July, as shown in the following tabulation:

Month	Percent	Month	Percent
January	2	July	19
February	2	August	16
March	4	September	10
April	10	October	5
May	13	November	3
June	15	December	1

Evapotranspiration

The potential evapotranspiration was computed using the Thronthwaite approach. Potential evapotranspiration thus computed is believed by Blaney and others to closely approach the free water evaporation when the surrounding terrain has complete vegetal cover. In many areas of the Columbia Basin this is not the existing condition.

Potential annual evapotranspiration in the Columbia-North Pacific Region ranges from 15 inches in some of the mountains east of the Cascade Range to 30 inches in the arid and semiarid areas. Actual annual evapotranspiration ranges from less than 10 inches, in some arid and semiarid areas where precipitation is scanty, to 22 inches in the valleys west of the Cascade Range, where moisture is more abundant. Actual evapotranspiration usually is only 50 to 70 percent of potential because the water supply is generally limited, especially during summer.

Storms

Tornadoes and hurricanes seldom occur in the region but hailstorms occasionally cause damage to crops east of the Cascade Range. Heavy rains that cause floods are common in winter west of the Cascade Range, and convective storms that produce cloudburst-type rains which cause severe flooding are not uncommon in summer east of the Cascade Range.

Winter storms that created above-normal mountain snowpacks helped set the stage for the great flood of May-June 1948 in the Columbia River Basin. The immediate cause was a sequence of temperatures conducive to production of a flood from snowmelt. During April and early May temperatures were subnormal, so that melting of

snows in the high mountains was delayed. Records indicate that the water content may have exceeded 200 percent of normal in some areas. At mid-May, temperatures rose generally to far above normal in the upper basin and remained abnormally high. During the latter part of May precipitation totals of 2 to 3 inches were recorded in much of the upper basin. With this combination of climatological events a great flood was born that reached a peak discharge of 1,010,000 cfs at the gaging station near The Dalles, Oregon.

Calendar year 1964 was one of the stormiest of record. The storms began June 7 in the Clearwater Basin and on June 9 in the Upper Clark Fork Basin, particularly on the Flathead River at Columbia Falls, Montana, where the highest flows for the period of record occurred. This flood, caused by torrential rainfall (probably over 16 inches in 30 hours), when added to the regular spring runoff would have caused an estimated $36 million damage. However, flood-control operations at Hungry Horse Reservoir reduced the estimated damage $12 million. The floods of December throughout Oregon and in parts of Washington and Idaho were the most damaging in the history of the area. The floods resulted from a series of storms in late December, but primarily from the warm torrential rainfall of December 21-23. This rainfall reflected the combined effect of moist unstable airmasses, strong west-southwest winds, and mountain ranges oriented nearly at right angles to the flow of air. Melting snow augmented by rain falling on frozen ground provided excessive quantities of runoff. As much as 20 inches of rain fell in some areas. The suspended-sediment concentrations and loads of most streams greatly exceeded any that previously had been measured in the flood-affected area. The ground thaw that occurred during the flood period resulted in conditions conducive to severe erosion of the uplands and subsequent silt deposition on flooded stream terraces.

The hurricane-force winds that struck the west coast of Washington and Oregon, October 11-13, 1962, resulted in one of the major weather catastrophies in the region's history. Winds exceeding 100 mph were recorded at a number of places, with record of peak gusts lost at most stations because of power failures. Three storm centers reached the coast in rapid succession and resulted in three days of high winds and excessive rains that caused damage of about $250 million and took an estimated 50 lives. In western Oregon, 84 homes were destroyed and more than 5,000 severely damaged. An estimated 70,000 telephones were out of operation and some 400,000 to 500,000 homes were without electric power. In western Washington, 39,000 telephones were out of service and property damage was high. An estimated 400 million board feet of timber was blown down.

A similar, but more severe, windstorm occurred on January 29, 1921, when the estimated maximum wind velocity was 112 mph and about 6 billion board feet of timber was badly splintered and blown down.

Humidity

The atmosphere west of the Cascade Range is naturally moist because of its proximity to the sea and the frequency of storms in winter. Stations nearest tidewater show the highest average relative humidity. The average usually is more than 80 percent throughout the year on the ocean coast; but at interior stations it is somewhat below 80 percent during the warmest part of winter days and generally drops below 50 percent in the late afternoon throughout much of the summer. Periods of unusually low humidity accompany east and northeast winds causing extreme fire danger.

East of the Cascade Range there normally is a wide range in the relative humidity from the time of occurrence of minimum temperature in the morning to the time of maximum temperature in the afternoon. The humidity is comparatively high in winter months, although in the warmer half of the year it is moderate to low, and in summer afternoons it is generally from very low to extremely low.

Sunshine

Cloudiness shows a marked variation from summer to winter throughout the region. Marine influence, combined with normal storm patterns in winter, causes much cloudiness west of the Cascade Range. In the western valleys there are about 75 clear days a year, 85 partly cloudy days, and 200 cloudy days. In the mountains, there are more cloudy days. Expressed somewhat differently, the amount of sunshine received each month ranges from approximately 20 percent of the amount possible in winter to 65 percent or more in summer.

East of the Cascade Range there is more sunshine, about 110 clear days, 90 partly cloudy days, and 160 cloudy ones. The amount of sunshine received each month ranges from about 20 percent of the amount possible in winter to 80 percent or more in summer.

Local areas vary somewhat from the above figures. For example, in much of Subregion 12 the sun shines about 50 percent of the time possible in winter.

SURFACE WATER

The Columbia River is the principal stream draining the Columbia-North Pacific Region. Excluding that part in Canada, the basin contains 219,392 square miles or 80 percent of the region's total drainage area, and discharges an average of 168,850 cfs or 54.5 percent of the water in the region. The Canadian contribution to the Columbia River is about 73,000 cfs from 39,500 square miles of drainage area. Subregion 12 is the only part of the region

lying east of the Cascade Range that is not tributary to the Columbia River Basin. Even though that subregion represents 6.5 percent of the region's area, it contributes less than 1 percent of the water. The Puget Sound and Coastal Subregions include only 13.5 percent of the region's area but contribute 45 percent of the water discharged. Geographic differences in mean annual runoff are shown in figure 8. Figure 8A (watershed area and runoff diagram) shows the accumulated average annual runoff and drainage areas at various points for the Columbia River and tributaries, for the 50-year period 1897-1946.

The Rogue River in southern Oregon is the largest coastal stream draining directly into the Pacific Ocean. It has an average discharge of 11,300 cfs at Gold Beach from a drainage area of 5,160 square miles. The largest stream draining into Puget Sound is the Skagit River with an average discharge of 16,400 cfs at Mount Vernon from a drainage area of 3,093 square miles, including 400 square miles in Canada.

Quantity

The total average discharge produced from within the region, under 1970 conditions of development, is 310,000 cfs. About 66 percent of this water originates on the west side of the Cascade Range on about 20 percent of the region's area. In addition, Canada contributes about 74,000 cfs, making a total of 384,000 cfs or 278 million

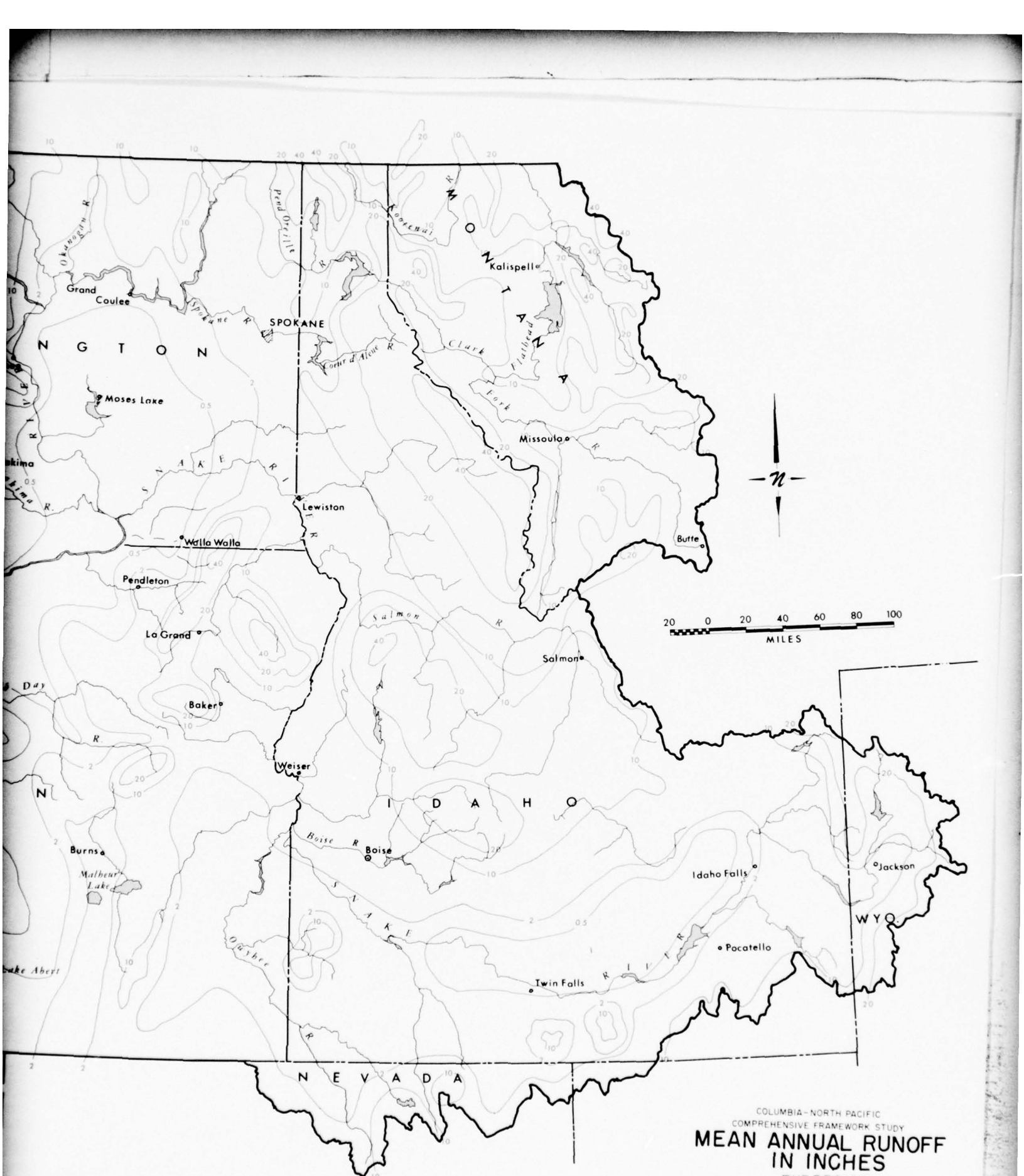
Table 1 - Water Withdrawn and Consumed for All Uses in Various Regions of the Conterminous United States, 1960

Region	Average Runoff (gpd) 1/	Average Runoff (mgd) 1/	Water Withdrawn (mgd) 1/	Water Withdrawn Percent 1/	Water Consumed (mgd) 1/	Water Consumed Percent 1/
Columbia-North Pacific	44,900	252,000	32,000	13	8,400	3
South Pacific	4,300	64,000	33,000	52	13,000	20
Great Basin	9,500	10,000	7,000	70	3,300	33
Colorado	7,400	13,000	14,000	108	7,100	55
Upper Missouri	4,600	28,600	20,200	71	7,450	26
Upper Arkansas-Red	3,200	11,000	5,500	50	3,200	29
Western Gulf	5,200	52,000	22,000	42	9,200	18
Upper Mississippi	5,100	62,000	11,000	18	570	1
Lower Missouri	10,000	23,000	1,600	7	200	1
Lower Arkansas-Red-White	19,000	79,000	4,900	6	850	1
Lower Mississippi	10,500	49,000	5,300	11	1,300	3
Southeast	10,400	209,000	18,900	9	2,010	1
Tennessee-Cumberland	13,400	59,000	7,500	13	400	1
Ohio	6,000	110,000	24,000	22	800	1
Western Great Lakes	3,100	42,000	16,000	38	510	1
Eastern Great Lakes	3,200	40,000	13,000	32	420	1
Chesapeake	5,000	51,000	7,100	14	320	1
Delaware-Hudson	1,400	32,000	20,000	62	830	3
New England	6,600	67,000	6,400	10	290	1

1/ Definitions: gpd - gallons per person per day.
mgd - millions of gallons per day.
percent - percent of average annual runoff.

Note: Columbia-North Pacific runoff includes 45,000 mgd inflow from Canada.
Source: G. L. Bodhaine and others (4).

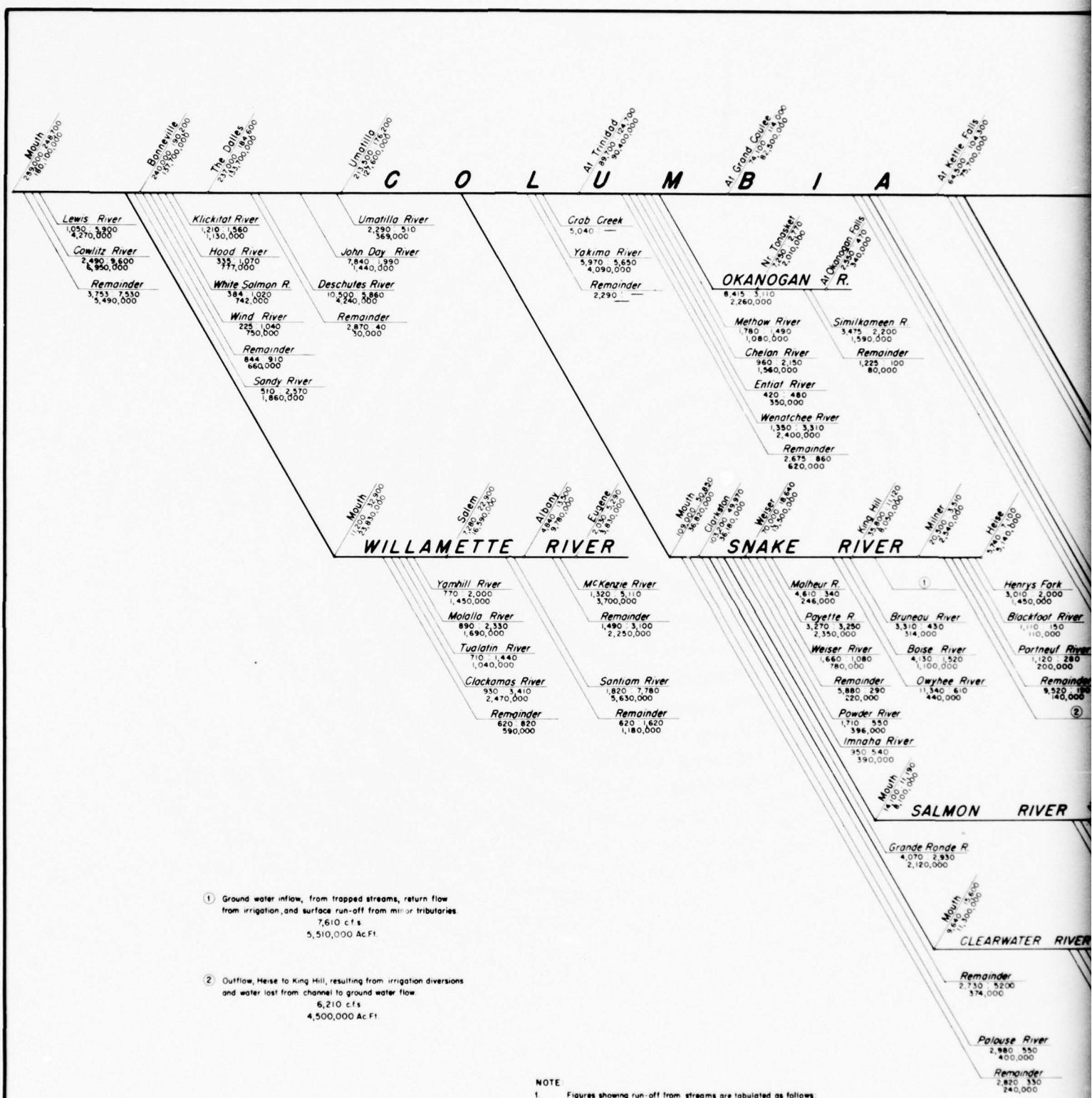

Bellingham
Everett
SEATTLE
TACOMA
Olympia
Hoquiam
Aberdeen
Quinault R.
Chehalis R.
Wishkah R.
Wynoochee R.
Satsop R.
Humptulips R.
Queets R.
Quillayute R.
Hoh R.
Bogachiel R.
Quillayute
Longview-Kelso
Astoria
Tillamook
Vancouver
PORTLAND
Willamette R.
Salem
Newport
Eugene
Siuslaw R.
Umpqua R.
Coos Bay
Roseburg
Rogue R.
Grants Pass
Medford
Wenatchee
Yakima
Yakima R.
Grand Coulee
Okanogan R.
Pend Oreille R.
Spokane R.
SPOKANE
Coeur d'Alene R.
Moses Lake
Columbia R.
The Dalles
Deschutes R.
Pendleton
Walla Walla
Lewiston
Snake R.
La Grand
John Day R.
Baker
Weiser
Bend
Burns
Malheur Lake
Lake Abert
Owyhee R.
Boise R.
PACIFIC OCEAN
WASHINGTON
OREGON
NEV



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES
THE REGION
1968

FIGURE 8



(1) Ground water inflow, from trapped streams, return flow from irrigation, and surface run-off from minor tributaries.
7,610 c.f.s.
5,510,000 Ac.Ft.

(2) Outflow, Heise to King Hill, resulting from irrigation diversions and water lost from channel to ground water flow.
6,210 c.f.s.
4,500,000 Ac.Ft.

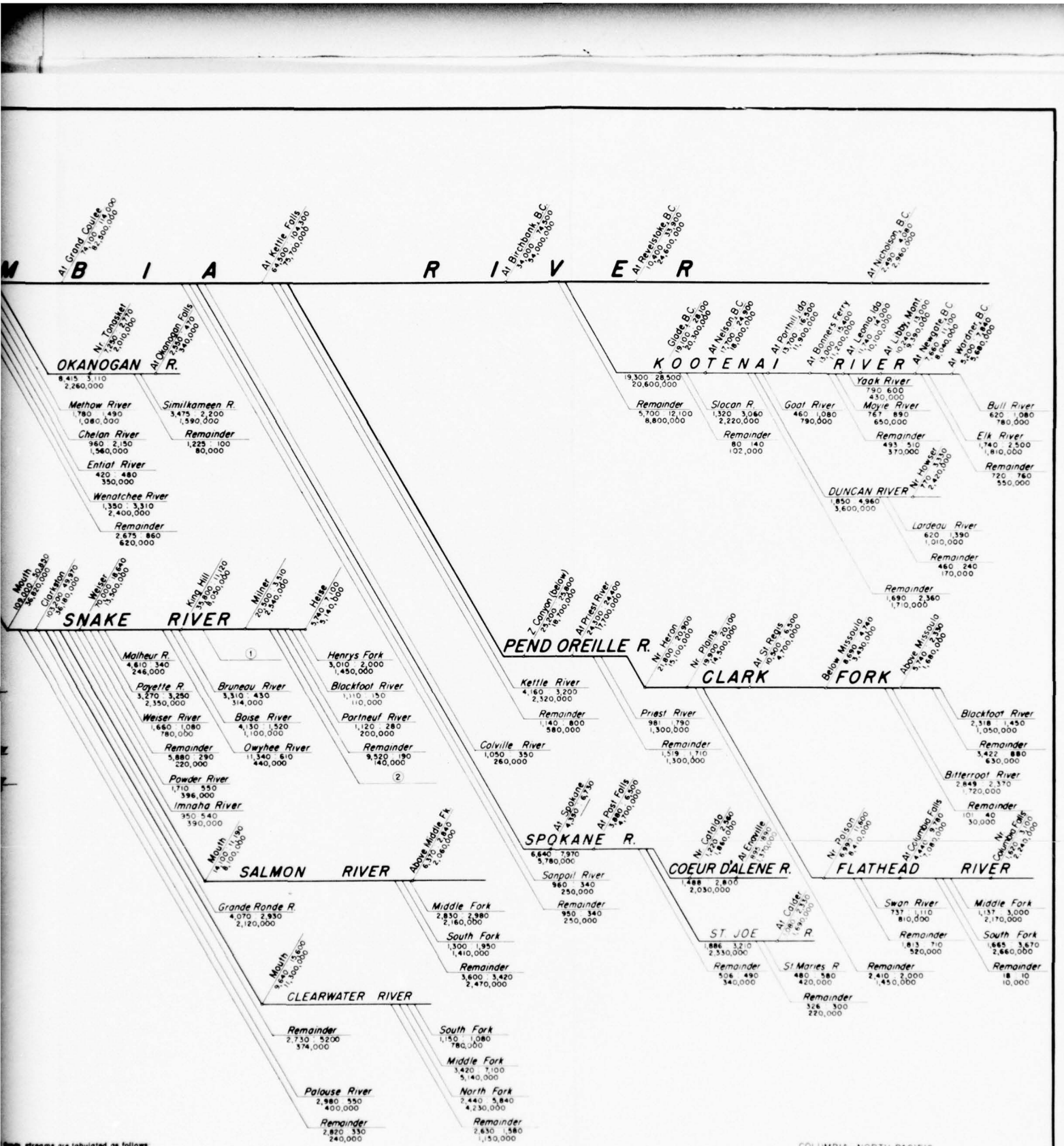
NOTE:

1. Figures showing run-off from streams are tabulated as follows:

Drainage area in square miles : Average annual run-off in c.f.s.
Average annual run-off in acre-feet

2. Average annual run-off based on 50-year period, 1897-1946. (Water years)

3. Flows are observed or estimated observed for the period indicated.



Main streams are tabulated as follows:

Miles : Average annual run-off in c.f.s.
Annual run-off in acre-feet

For 50-year period, 1897-1946. (Water years)

Adjusted observed for the period indicated.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

WATERSHED AREA AND RUNOFF DIAGRAM

THE REGION

1968

FIGURE 8A

acre-feet annually. Of this, the Columbia River discharges 239,700 cfs (175.7 million acre-feet) or almost 64 percent of the total.

National water-use data for 1960 are shown in table 1 for average runoff, water withdrawn, and water consumed in various parts of the United States. The greatest quantities of runoff occur in the Columbia-North Pacific and Southeast Regions, with the per-person availability being largest in the Columbia-North Pacific Region. This region, however, withdraws and consumes a greater percentage of its water than several other regions, such as New England and the Southeast. In fact, in some areas such as Subregions 4 and 5, irrigation probably depletes streamflow more than 30 percent, placing this part of the region in as high a consumption category as the other regions in western United States.

Present Utilization

East of the Cascade Range water withdrawals for irrigation account for more than 95 percent of the water diverted for consumptive purposes. West of the Cascade Range, in the more populated areas, 70 percent of the withdrawals for water-consuming purposes is for public water supply and self-supplied industrial uses. For the entire region, irrigation accounts for more than 95 percent of the consumption of withdrawn waters. Thermal power is relatively unimportant at present, as practically all the electrical power produced is hydroelectric. Counting the water each time it passes through a plant, about 838 million acre-feet of water is used annually in the production of hydroelectric energy. Navigation is important on the lower reaches of the Columbia River and its main tributaries, the Willamette and Snake Rivers. A few of the smaller streams, such as the Skagit River, are also used for navigation, and estuaries provide harbors for ocean-going vessels. Recreation is rapidly becoming an important water use. All waters are used to some extent for fish and wildlife. The abundance of water in most areas has led to its general use in transportation and dilution of waste, but pollution has become a problem in certain areas where such use is intensive.

Data showing comparative diversion or withdrawals of water for, and estimates of water consumed by, various purposes in 1965 are listed in table 2. These figures were prepared in 1967 by the Subcommittee on Coordinated Planning, Pacific Northwest River Basins Commission, as a part of the National Assessment of water use. The functional appendices will contain more recent data.

Stream Management

The measurement, storage, release, regulation of diversions,

flow guidance, and conservation of the waters constitute stream management. Competition for water among the myriad of users has necessitated effective stream management to insure that each use receives its fair or legal entitlement. Considerable progress has been made toward efficient stream management, and a brief summary of present arrangements and constraints includes the means for physical control of the streamflow, the criteria for control, and the legal restrictions and constraints involved. The stream-management system has been outlined first by international and national agencies. The Columbia Basin Inter-Agency Committee and, more recently, the Pacific Northwest River Basins Commission have

Table 2 - Water Used in 1965, Columbia-North Pacific Region[1/]

Sub-region	Public Supplies	Self-Supplied Industry	Irrigation	Total Consumptive Uses	Power	Recre-ation
	1000 acre-feet					1000 acres
			Water Withdrawn			
1	146.9	114.6	1,587	1,879	105,906	452
2	45.4	14.4	2,896	2,971	316,174	288
3	38.6	9.1	2,395	2,463	1,671	28
4	50.1	64.1	12,755	12,896	37,308	266
5	43.6	87.8	5,932	6,089	42,746	171
6	28.1	122.9	791	953	25,619	81
7	62.8	186.0	1,866	2,126	256,473	95
8	19.7	370.2	31	424	12,415	74
9	202.7	571.6	389	1,214	18,641	106
10	132.4	296.0	262	712	4,798	154
11	465.2	264.2	172	952	16,066	101
12	2.4	33.6	498	538	0	94
TOTAL	1,237.9	2,134.5	29,574	33,218	837,817	1,910
			Water Consumed			
1	23.7	12.7	638	700		
2	10.9	1.1	1,346	1,372		
3	9.2	.7	952	979		
4	2.9	4.9	4,138	4,169		
5	3.0	9.7	2,311	2,345		
6	3.6	1.8	320	336		
7	22.4	6.8	674	712		
8	2.0	3.9	15	22		
9	40.3	25.2	272	377		
10	20.8	15.1	158	212		
11	63.8	28.9	105	234		
12	1.1	.6	321	326		
TOTAL	203.8	111.4	11,252	11,785		

1/ Compiled from data prepared for the first National Water Assessment. More accurate data may be given in the functional appendices.

established many guidelines. Among these are fitted the rules of the operating agencies or organizations, which, in turn, control the individual sets of project operations.

Physical control and management of the streams include the development and operation of storage and diversion facilities and the maintenance or modification of channels.

There are more than 160 impoundments in the region having total capacities greater than 5,000 acre-feet. Usable storage capacity of the principal reservoirs and regulated lakes in 1960 was nearly 30 million acre-feet; by 1970 it will be about 42 million acre-feet. A number are multi-purpose in that they serve two or more purposes. Main functions of the reservoirs include flood control, recreation, hydroelectric power generation, irrigation, navigation, municipal water supply, and fishery enhancement. Generally, power generation is the most widespread function of the region's impoundments. Irrigation and flood control are also significant. While not the primary stimulant for reservoir construction, extensive recreational use is a major result and continues to grow. Fishery enhancement is not as significant as are other functions, but minimum flows are maintained in many streams for this use.

Diversions are widespread over the region, most being for irrigation. Many of the agricultural areas rely on stream diversion to augment a deficient water supply during the growing season. Much of the water management is carried on by individuals, districts, and State Watermasters regulating flow to meet the distribution requirements of conflicting uses. Most diversion takes place in the eastern subregions.

Channel modification is not as significant as the other operations but is employed almost everywhere to some extent. Most of the modifications concern flood control, conservation, and navigation and consist of levees, revetments, dikes, channel rectification, and dredging. The modifications are undertaken only when economically justifiable. Concentration of this operation is in the Willamette Subregion, but some major streams in other subregions have been modified considerably. Channel modification has frequently had an adverse effect on recreation and fish.

The criteria for control of stream flow include first the forecasting of amounts and then the establishment of elevation limits for storage and maximum and minimum rates of flow. Forecasting is used chiefly in flood warning and to provide a maximum of stored water for irrigation, power generation, and municipal use. Existing flood-warning systems in the Willamette and Puyallup River basins combine Telemark instruments with radio transmission from several outlying locations to central points. The Weather Bureau also operates a general flood-warning system in times of

major flood danger.

Forecasts of seasonal quantities of water available for storage are made using data on snow surveys, precipitation, antecedent conditions, and other parameters. These are processed by digital computer and results are updated each month as new data are obtained. In addition, the distribution of runoff for the Columbia River and tributaries is forecast daily by computer during the period of heavy runoff.

There are many legal restrictions and other constraints to stream management. The most important are the international treaties, such as the Boundary Waters Treaty with Canada, signed on January 11, 1909, and proclaimed by the President on May 13, 1910. For boundary waters it provides navigation restrictions; control of use, diversions and obstructions; pollution control; and an International Joint Commission with jurisdiction over these matters. (See Appendix III for more detail.)

Another treaty with Canada, relating to Cooperative Development of the Water Resources of the Columbia River Basin, was signed on January 17, 1961, and became effective on January 22, 1964. It provides for the construction of Duncan, Arrow, and Mica Dams by Canada within 9 years and for the construction of Libby Dam by the United States by 1972. Power and flood-control benefits are described, including the manner of sharing them by both countries. Provisions are made for diversions, designation of operating entities, establishment of a Permanent Engineering Board, limitations on liabilities for damages, and eventual restoration of the pre-Treaty legal position.

During the period 1854-56, the United States made some 11 treaties with Indian tribes of the Pacific Northwest. The treaties generally provided that the Indians were to have the right to fish both on and off specified reservations. Accordingly, it is possible that some use of the water or waterways will be affected by these provisions. Also, the United States Supreme Court has held that, with respect to the rights reserved by the United States for irrigation of Indian reservations, the waters involved are exempt from appropriation under State law. This has resulted in restriction of the right to use water from those streams which flow through or are adjacent to the boundaries of Indian reservations.

A state compact affecting stream management is the Snake River Compact ratified by Idaho and Wyoming in February 1950.

Still other agreements affecting stream management are a land-use agreement between the city of Seattle and Canada concerning Ross Reservoir on the Skagit River; the Water Supply Act of 1958 providing space for water supply at Federal storage projects,

such as the Upper Rogue River Basin; and, of course, the many state water rights.

Some Federal Power Commission licenses include provisions limiting the flow, or the rate of change in stage, below specified powerplants, and the license for Mossyrock on the Cowlitz River stipulates operation for control of floods.

In September 1964, the Pacific Northwest Coordination Agreement, effective until the year 2003, was consummated by 16 electrical power systems of the Pacific Northwest. Included in the agreement were all members of the Northwest Power Pool that were involved in the development of the non-Federal run-of-river projects on the Columbia River. As the basis for the agreement, they set forth 12 principles which provided that downstream parties should have certain rights in the regulation of upstream storage. In exchange for these rights, the downstream parties would pay a share of the costs of building, maintaining, and operating the upstream storage project. Other rights and obligations of parties were also included in the principles.

The Agreement is a complex and detailed contract providing many forms of coordinated operations. At the same time it contains certain basic fundamentals of coordination. It provides that system-regulation studies will be made wherein the most adverse historical streamflow sequence (critical streamflow period) for the Pacific Northwest as a whole is regulated by the existing hydroelectric system to serve the next year's estimated load demand. These studies determine on a monthly basis the firm energy each of the coordinated systems could produce on a coordinated basis with a recurrence of critical flow conditions. Each party to the agreement is entitled to the amount of energy thus determined for his system and all parties agree to mutually support one another in producing this power in actual operation.

As a result of the Coordination Agreement, it is possible for the owner of a run-of-river hydro project, with no upstream storage under his control, to be assured of an amount of firm energy greatly in excess of that his project could produce without coordination. This concept of guaranteed firm energy is fundamental to the Agreement.

Operation under the Agreement provides two methods for a party to secure firm energy. The end-of-month elevations or storage contents of all storage reservoirs during the critical streamflow period are determined from the system regulation study which computed the firm energy amounts. These elevations define a critical rule curve. A downstream party has the right to call for storage releases down to the critical rule curve from the storage reservoir of any upstream party. He also has the right to purchase interchange

energy from any other party whose actual energy resource is in excess of his firm energy.

In fulfilling the request of a downstream party for storage release the reservoir owner has an option: He may either release the storage as requested or supply the downstream party with energy in lieu thereof or some combination of the two. This provision of the Agreement prevents the waste of energy in the coordinated system.

Among present arrangements for managing the waters of the region, the constraints involved in the Flood Control Operating Plan for Columbia River Treaty Storage are probably the most extensive, affecting all major storage reservoirs of the Columbia River Basin. The plan provides runoff forecast procedures, both day-to-day and seasonal.

In general, reservoir storage space for flood control operation should be available by April 1 of each year because of possible flooding during April, inability to evacuate during April, and the desirability for major lakes to recede naturally to normal minimum elevations before the flood period.

Since normal power operation does not guarantee the available space for flood control, reservoir releases are based on monthly runoff volume forecasts.

Reservoir refill is based on five categories as follows: (1) reservoirs with fixed releases operated primarily for flood control of the lower Columbia River; (2) those operated for tributary flood protection, with incidental lower river protection; (3) major lakes controlled by dams during low-flow periods; (4) reservoirs with variable releases operated primarily for flood control of the lower Columbia River; and (5) run-of-river projects.

The primary period of flood regulation, during which the Flood Control Operating Plan takes precedence over other operations is defined as commencing 20 days before the date the unregulated mean daily discharge is forecast to exceed 450,000 cfs at The Dalles, and ending when the Flood Control Committee declares further flood potential no longer exists.

In operation for irrigation, in order to insure refilling the reservoirs, the evacuation for other purposes is based on storage reservation diagrams.

In general, constraints include maintenance of sufficient minimum flow to satisfy prior water rights, adequate flow for normal resident fish population and anadromous fish runs, adjustments to accommodate navigation, and releases in the interests of pollution

abatement. All of this requires stipulations at each project of maximum and minimum outflows, maximum allowable rate of change in outflow, and minimum and normal full pool elevations.

The Bureau of Reclamation, the Bonneville Power Administration, and the Corps of Engineers have agreed to sponsor the Columbia-River Water Management Group, which acts as a committee to consider problems relating to operation and management of water control facilities. The committee makes recommendations to the individual agencies having primary responsibilities. Particular emphasis is placed on coordination of river-system operations including the efficient performance of a hydrometeorological system required for operation. The basic objective of the Group is to facilitate agreement among the agencies in the interest of more effective and efficient public service in the use of the water resources of the Pacific Northwest. The Group is composed of representatives of the States and of the Federal agencies involved in the operation and management of water-control facilities or forecasting of streamflows related to water management activities in the Columbia River Basin and contiguous areas in western Washington and Oregon.

Additional constraints and reservations apply to other federally owned or reserved lands. These are discussed in detail in Appendix III, Legal and Administrative Background.

The result of the widespread and varied water-management effort has been to reduce winter and spring flood-flow runoff through upstream storage, to improve low-season flows at some points, and to sharply reduce flows below large diversion works. These effects are reflected in the modified flows analyzed in this appendix.

Surface-Water Rights

Water rights for each subregion have been discussed in some detail in each subregion report. General comments applicable to each state are listed in this section of the report.

Idaho Some of the earliest extensive irrigation diversions in modern America were in Idaho. In 1837, a mission near Lewiston diverted irrigation water from Lapwai Creek. Irrigation began in the Lemhi Basin in 1855, and in Bear Lake Valley in 1860.

In 1881, the Idaho Territorial Legislature passed a law regulating the appropriation of water and, in 1887, stated "that the right to the use of flowing water may be acquired by appropriation, and as between appropriations priority in time shall secure priority of rights." The Constitution of Idaho provides that "the

right to divert unused water from any natural stream to beneficial use shall never be denied, except that the state may regulate and limit the use thereof for power purposes." Priority for use is given to the right first in time between those using water; but, when the water of any natural stream is not sufficient for the services of all those desiring to use it, those using the water for domestic purposes shall have first preference over those claiming it for other purposes, and those using the water for agricultural purposes shall have preference over those using it for manufacturing.

Montana The Montana Supreme Court in 1921 declared that the Doctrine of Appropriation was the valid Montana water-right law. The right is limited to the use of the water. Streams in Montana are the property of the state and the appropriator acquires only the right to their use, and this use must be beneficial.

A water right in Montana can be lost either by abondonment or by adverse possession. The courts have held that the right to use water is a property right on real estate (so much so that it passes with the land even if not mentioned in the deed); therefore, it follows that, if a person uses another's water right for 5 years adversely, openly, continuously, uninterruptedly, notoriously, and when the other needed the water, the person may acquire another's water right by adverse use.

Inasmuch as the Montana laws do not require water users to file official records of the completion of their appropriations, and there are no restrictions on the size of an appropriation for beneficial use, the waters of a stream may become overappropriated and the demand may exceed the supply. Appropriators are required to file at the county level and must post notices of appropriations. The quantity of appropriated water is a record of the rights to use water claimed under existing statutes. In the case of an adjudicated stream, the quantity of appropriated water is the record of water rights fixed by the court decree and might be a measure of the crop irrigation requirement and of the quantity of water available for use.

Nevada The basic concept of the present Nevada Water Law was developed from the Act of 1903 which declared that all natural water courses and natural lakes, and the waters thereof, belong to the public and are subject to appropriation for a beneficial use. The act also declared that the right to the use of water so appropriated for irrigation shall be appurtenant to the land to be irrigated, and beneficial use shall be the basis, the measure, and the limit of the right. The Act of 1913 provided a law for the conservation of underground waters and declared all sources of water supply within the boundaries of the state, whether above or beneath the

surface of the ground, belong to the public.

Most of the surface water originating in the region in Nevada is used in Idaho, and many of the water rights have been transferred from Nevada to properties in Idaho. Only a few wells have been drilled for irrigation purposes in Nevada and the quantity of ground water used is very small.

Water-rights data in Nevada are being summarized but the results are not available at this time.

Oregon All waters within the State of Oregon from all sources (except a spring which does not flow into a well-defined channel and off the property of origin, under natural conditions) are declared by statute to belong to the public.

Subject to existing rights, all public waters within the state except those which may have been withdrawn by legislative action or by order of the State Engineer or by the Water Resources Board may be appropriated for beneficial use by complying with the requirements of the Surface Water Code or the Ground Water Act, and not otherwise.

Oregon is essentially an appropriation-doctrine state, and the terminology "riparian rights" has become little more than legal fiction. In cases brought before the Oregon Supreme Court it has held that the 1909 Water Code validly abrogated the common-law riparian rule except where the water had actually been applied to beneficial use prior to its enactment, which, in effect, makes it an appropriative right.

The appropriation of the surface waters of the State of Oregon, which include the waters of rivers, lakes, streams, springs, waste waters, and waters stored in reservoirs and other surface sources, is governed by provisions of the Surface Water Code, which was adopted on February 24, 1909, and subsequent acts. Nothing in the Code, however, is so construed as to take away or impair the vested right of any person, firm, corporation, or association to any right for surface waters which was initiated prior to February 24, 1909.

A legal right for any surface water appropriation initiated after February 24, 1909, can be established only through application of water to beneficial use under the terms of a water right permit issued by the State Engineer. A claim to a vested right by virtue of use prior to February 24, 1909, and continued use thereafter, can be determined and made a matter of record only through a legal proceedings, known as an adjudication. This proceeding involves several administrative steps by the State Engineer and is

concluded by a decree of the Court.

Adjudication proceedings have been completed for most of the major stream systems in eastern and southern Oregon, but only for a few of the stream systems in the remainder of the state.

New water rights are obtained through the State Engineer and the water right remains valid and in force so long as it is not lost through intentional abandonment or through nonuse for a period of 5 successive years or more. Under this system as of July 15, 1969, there had been issued 5,404 reservoir permits and 34,009 surface water permits.

With the establishment of the State Water Resources Board in 1955, a single agency was created to hold hearings and issue state water policy statements on unappropriated water for each of the river systems in Oregon. These water policy statements, among other things, may set minimum flow requirements and limit partially or entirely uses to which water may be put.

While subsequent applications for water rights are subject to the provisions of the water policy statement, nothing in the statement is construed to take away or impair any right to any water or to the use of any vested and inchoate right acquired prior to the adoption of the State Water Resources Board policy.

Some restraints to the appropriation of water may be contained in the State Water Resources Board water policy statements. Other withdrawals are statutory in nature under Chapter 538 of the Oregon Revised Statutes. Also the State Engineer has withdrawn certain streams from further appropriation. Detailed limits such as duty, season of use, and total unused quantities are stated in the permits and court decrees.

The State Engineer has authority to declare critical ground water areas and may limit well drilling or impose other rules in these areas to prevent mining of the ground water.

While requirements of the State Sanitary Authority do not directly affect diversions of water, they can have a very real and practical effect in limiting the condition of the waters returning to the streams. Construction of diversion structures and pump stations are subject to rules and regulations of the State Fish and Game Commissions.

The State Engineer administers distribution of water in the state through a system of 15 watermaster districts. Records of gaging stations (not available in the USGS water supply papers) established for water administration are published and available upon request.

Utah All waters in the State of Utah, whether above or under the ground, are the property of the public and beneficial use is the basis, the measure, and the limit of all rights to the use of water in the state. All applications for the appropriation of water must be made to the State Engineer, and between appropriators, the one first in time shall be first in rights. No right to the use of water, either appropriated or unappropriated, can be acquired by adverse use or adverse possession.

Washington In the State of Washington the basis for most laws governing the appropriation of surface waters is set forth in Chapter 117, Laws of 1917. This chapter, now known as the Surface Water Code, firmly established the appropriative doctrine but recognized existing rights of riparian owners and other users that were existing prior to the effective date of the code. To fix the extent of these precode rights, an adjudication procedure was also established.

The agency presently responsible for administering the state water code is the Department of Water Resources. This agency had on record as of April 30, 1967, approximately 16,838 active surface water-right records in the form of permits and certificates established under the standard appropriation procedure and by adjudication. During the summer period when low flows are critical, the recorded prime rights under both procedures allow diversions totaling 1,232,611.67 cfs from all surface-water sources in the state. Of this total, 18,139.59 cfs is used consumptively, 52,870.62 cfs is partially consumptive to the various sources of supply, and 1,161,504.14 cfs of the total diverted water is nonconsumptive to the surface waters of the state. Definitions of the terms consumptive, partially consumptive, and nonconsumptive are as follows:

Consumptive, Surface Water (1) Where there is a definite diversion of water from a surface-water source and, neglecting transportation losses (seepage and evaporation), the full amount of the diversion is not returned directly to the original source body or any other surface-water body by means of a definite surface-water course, channel, or pipe. (2) Where there is a definite diversion of water from a surface-water source for a consumptive type of use such as: irrigation, domestic supply, etc.

Partially Consumptive, Surface Water (1) Where the full amount of diversion from a surface-water source (neglecting transportation losses) is returned to the same surface-water source at a point farther than 25 feet downstream from the point of diversion. (2) Where the full amount of a diversion from a surface-water source (neglecting transportation losses) is returned to another tributary source within the same drainage system. (3) Where the full amount of a diversion from a surface-water source (neglecting transportation

losses) is returned to another surface-water source outside the complete drainage system (to salt water) in question.

Nonconsumptive, Surface Water (1) Where no water is diverted from the confines of the surface-water source area or channel. (2) Where the waters used under a right pass over, through, or around an onstream project structure without passing outside of the natural confines of the stream channel. (3) Where the waters used under a right are diverted (effectively) at the upstream edge of a project structure and the full amount of the diversion (neglecting transportation losses) is returned to the same stream channel (effectively) at the downstream edge of the project structure. (4) Where the full amount of a diversion from a surface-water source (neglecting transportation losses) is returned to the same surface-water source no farther than 25 feet downstream from the point of diversion. (5) Where the full amount of a diversion from a surface-water source is returned to the same source at any location upstream from the point of diversion (neglecting transportation losses).

In addition to prime-right quantities, 782.92 cfs has been allocated under supplemental rights. Such rights allow a water user the privilege of obtaining his needed supply from one or more additional or alternative sources, but a supplemental right does not increase the diversion quantity permitted under the original prime right held by the water user.

All surface-water rights involving consumptive diversions are presently issued with total annual quantity limitations. This practice, however, has only been in effect for a relatively short time; thus the total annual limitation of surface-water diversions cannot be accurately assessed from existing records.

Recorded reservoir-storage rights (permits and certificates) in the State of Washington allow a total of 12,337,436 acre-feet per year to be retained in storage for eventual application to beneficial use. This figure does not include either vested storage rights obtained by virtue of use prior to 1917 or the rights of the Federal government associated with major dams and reservoirs on the main stems of the Columbia and Snake Rivers.

All water-right quantities in the State of Washington have been summarized by location in geographic units called "Water Resource Inventory Areas" (abbreviated W.R.I.A.). Each of these areas basically encompasses a major drainage basin and/or several small stream drainages. The location of each W.R.I.A. is shown on maps in the Water Rights sections of the subregion reports. The approximate relationships between groups of W.R.I.A.'s and the corresponding Columbia-North Pacific subregions are shown below:

Columbia-North Pacific Subregion	Approximate W.R.I.A.'s in Subregion
1	54-57, 62
2	36,40-53, 58-61
3	37-39
6	33-35
7	29-32
8	25-28
10	19-24
11	1-18

In each subregional water-right discussion, the legally appropriated quantities are generally presented in terms of total prime actual water-right quantities and total quantities that may be diverted for general purpose-of-use categories. Since water rights often specify a single quantity for two or more purposes of use, it is theoretically possible to use the entire quantity as a maximum for either use. Consequently, the summaries of quantities by use often involve considerable duplication and totals for all-use categories will generally exceed the actual prime water-right quantity total.

Wyoming Within the limitations of the Snake River Compact between Idaho and Wyoming, individual rights to the diversion of natural flow on the main stream of the Snake River and its tributaries are on a priority basis and have been established through numerous court decrees or through permits according to state law. Depending upon the state involved, these rights are given priority according to the date of the original filing or use, with the earliest priority dating back to 1880. Storage allocations are made to individual irrigators or reservoir owners each year according to the amount of space owned in the different reservoirs and the available water stored in them.

Discharge

The base period selected for the Columbia-North Pacific Region hydrologic study is 1929-58. Water years are generally used; however, the 3-month period, July-September 1928, is included to complete the fiscal 30-year period; and the fiscal-year data are used in power studies and in much of the program related to the Canadian Treaty.

Long-term streamflow records in the Pacific Northwest indicate that both very low and very high monthly and annual flows occurred during the base period. Records for the Columbia River

at The Dalles, Oregon, representing 72 percent of the entire regional area, show that the observed mean discharge of 171,300 cfs (including inflow from Canada) during the 30-year base period is about 88 percent of the long-term (87-year) mean. Quinault River at Quinault Lake, Washington, a typical coastal stream, shows a base-period mean discharge equal to 99 percent of its long-term (54-year) mean. The subregion reports show other examples where base-period means of typical streams are representative of long-term means. Thus, the selected base period provides reasonably average data for statistical analyses and other studies.

A primary reason for selecting the 1929-58 base period is that the same period has been used for many years by the Columbia Basin Inter-Agency Committee in its studies of modified flows at designated points in the Pacific Northwest. It is used by many individual agencies in their Columbia Basin and other water studies. Irrigation depletions and storage and regulation for flood control and power production are included in the determination of modified flows. These studies, which are programed for the digital computer, regularly undergo revision. Bonneville Power Administration's recent computer study number 75-8 was selected for use in this report. This study gives mean-monthly historical flows for the 30-year base period (fiscal 1929-58) modified for evaporation and irrigation depletions as of about the 1970 level of development, regulated for flood control by dams existing or under construction by 1970, and regulated for power production to meet anticipated 1975 level power loads. Discharges at some sites were modified a second time for more precise flood control operations. Many of the sites on mainstem and principal tributary streams used in the computer study are the same ones that are being used in the Columbia-North Pacific Study. Thus, considerable monthly flow data are readily available that would otherwise have required extensive computations. Also, recent modified flow studies of the Bureau of Reclamation have been used as data sources.

The discharge data used in this report are generally available in Geological Survey Water-Supply Papers 1316, 1317, 1318, 1736, 1737, and 1738 (compilations of monthly discharges), and from Bonneville Power Administration computer study 75-8. All of the monthly data used are shown in tables in the various subregion reports.

Isopleths of mean annual runoff for the region during the period 1931-60 are presented in figure 8. Each isopleth shows runoff generated only along that line.

Measurement Facilities One hundred and sixty-nine sites on both large and small streams were selected for detailed analysis. These sites, averaging 14 per subregion, are considered

representative of the various parts of the region and they include many gaging stations where long-term records have been collected. These sites were selected to provide detailed data on streams of interest to the agencies preparing the fundamental appendices. Also, this information is sufficient to guide the planners in evaluating water availability to satisfy the needs projected for various parts of the subregions. The specific locations, with station numbers, are shown on the runoff maps in the subregion reports. Site names and pertinent streamflow data are summarized in tables titled "Streamflow Summary for Selected Sites" in each subregion report. The mean annual flow values are average flows for the base period, as modified by regulation and irrigation depletions. The momentary flows are the observed extremes for the entire period of record at the site and are, in some cases, affected by regulation and depletions. Gage datum is mean sea-level datum of 1929.

Gaging stations are located at most of the selected sites and these are identified by the Geological Survey numbers that are commonly used in the Survey's annual publications. The full number contains eight digits, the first two represent the Part number (a number assigned to a large area covered by one volume of the Water-Supply Paper series published by the Geological Survey[1/]) and the other six, the last two of which are decimals, represent the specific location. In subregions where the entire area lies within one Part, the first two digits are not shown on the maps; also, when the two decimal digits are zeros, one or both of them may be dropped.

Average Discharge in Subregions The average discharge and the approximate flows that would be available 80, 90, and 95 percent of the time for the base period 1929-58 and reflecting 1970 levels of utilization are shown in table 3. The discharge for a subregion represents the flow originating in that subregion or outflow minus inflow. Inflow from Canada is added to complete the water-availability picture.

In the sections for Subregions 6 and 7 the tables, which show discharge for the subregion as a whole, contain an item referred to as unidentified discharge. This water is assumed to be used or lost along the main channel of the Snake and Columbia Rivers between the upstream and downstream ends of the subregions. On an annual basis, the loss amounts to nearly 2,500 cfs. This quantity, when added to the difference between outflow and inflow to the region, shows the water actually available for use in the tributary basins.

1/ Part 10 covers The Great Basin; Part 12 covers Pacific Slope basins in Washington and upper Columbia River Basin; Part 13 covers Snake River Basin, and Part 14 covers Pacific Slope basins in Oregon and lower Columbia River Basin.

Table 3 -Annual Discharge for the Columbia-North Pacific Region, 1970 Conditions, Base Period 1929-58

Subregion	Area Sq. Mi.	Average Discharge (cfs)	Flow Exceeded in Percent of Time 80	90	95
1	36,361	36,253	25,985	22,000	19,500
2	22,451	5,300	-1,800[1/]	-6,000[1/]	-8,700[1/]
3	6,062	3,240	1,776	1,400	1,200
4	35,857	8,590	7,044	6,700	6,600
5	36,825	7,748	4,856	3,100	2,500
6	35,081	29,939	22,968	16,700	15,200
7	29,606	13,869	11,469	7,100	5,900
8	5,103	24,971	16,988	15,100	14,200
9	12,046	38,490	21,869	17,200	15,000
10	23,763	87,615	57,813	46,500	39,000
11	13,355	52,113	40,864	36,100	33,400
12	17,904	1,650	670	400	300
U.S. Total	274,414	309,778	210,502	166,300	144,100
Canada	39,910	74,230	59,000	53,500	51,000
TOTAL	314,324	384,008	269,502	219,800	195,100

1/ Minus figures are caused by diversions and storage operations that are greater than the discharge that originates in the subregion.

Table 4 - Average Discharge, in CFS, by State, 1970 Conditions Base Period 1929-58

Sub-region	Idaho	Montana	Nevada	Oregon	Utah	Wash.	Wyoming	Total
1	11,328	22,350	-	-	-	2,575	-	36,253
2	-	-	-	-	-	5,300	-	5,300
3	-	-	-	-	-	3,240	-	3,240
4	1,843	-	138	-	28	-	6,581	8,590
5	5,761	-	772	1,215	-	-	-	7,748
6	26,300	-	-	3,400	-	239	-	29,939
7	-	-	-	9,260	-	4,609	-	13,869
8	-	-	-	-	-	24,971	-	24,971
9	-	-	-	38,490	-	-	-	38,490
10	-	-	-	52,919	-	34,696	-	87,615
11	-	-	-	-	-	52,113	-	52,113
12	-	-	-	1,650	-	-	-	1,650
TOTAL	45,232	22,350	910	106,934	28	127,743	6,581	309,778

If so used, however, the outflow from the subregions will be reduced accordingly.

Table 4 provides a breakdown of the regional discharge shown in table 3 to show the quantity of water contributed by each of the seven states concerned.

The monthly discharge of the region is shown in figure 9. This graph also shows, by month, the quantities of water originating on each side of the Cascade Range. Because high flows occur in winter west of the Cascade Range and generally in spring and summer east of it, their additive total provides a regionwide water availability greater than 275,000 cfs each month, November through June, as shown in figure 9. The low months are August and September when only 90,000 and 106,000 cfs, respectively, are available. Although only 20 percent of the region's area lies west of the Cascade Range, this area furnishes 66 percent of the regional runoff. The annual mean discharge that enters the United States from Canada is 74,000 cfs (1,000 cfs west of the Cascade Range), equal to 24 percent of the total supply originating in the region.

Each of the 12 subregion sections, which follow this Regional Summary, contains data applicable to the subregions as a whole as follows:

1. An isohyetal map based on the latest data from the Weather Bureau River Forecast Center for the period 1930-57.

2. A map showing lines of equal runoff for the period 1931-60.

3. Graphs showing mean monthly discharge for five conditions of flow: maximum, mean, minimum, and the 20- and 80-percent frequencies of occurrence.

Average Discharge for Selected Sites Data relating to the average discharge at the 169 selected sites are presented in detail in the subregion sections. Each section contains tables of monthly mean discharges for each site that represents either observed or modified flows depending upon the level of development and water use in the drainage basin. Observed flows are shown where there is little or no development, generally on the smaller streams in the mountains. Flows modified using Bonneville Power Administration computer study 75-8 were used directly or indirectly at several selected sites on main stream and major tributaries. Flows modified in recent Bureau of Reclamation studies were used for most sites in the Snake River Basin above Oxbow. Details on the computation of modified flows can be obtained from the above-named agencies. The selected sites are listed in table 5.

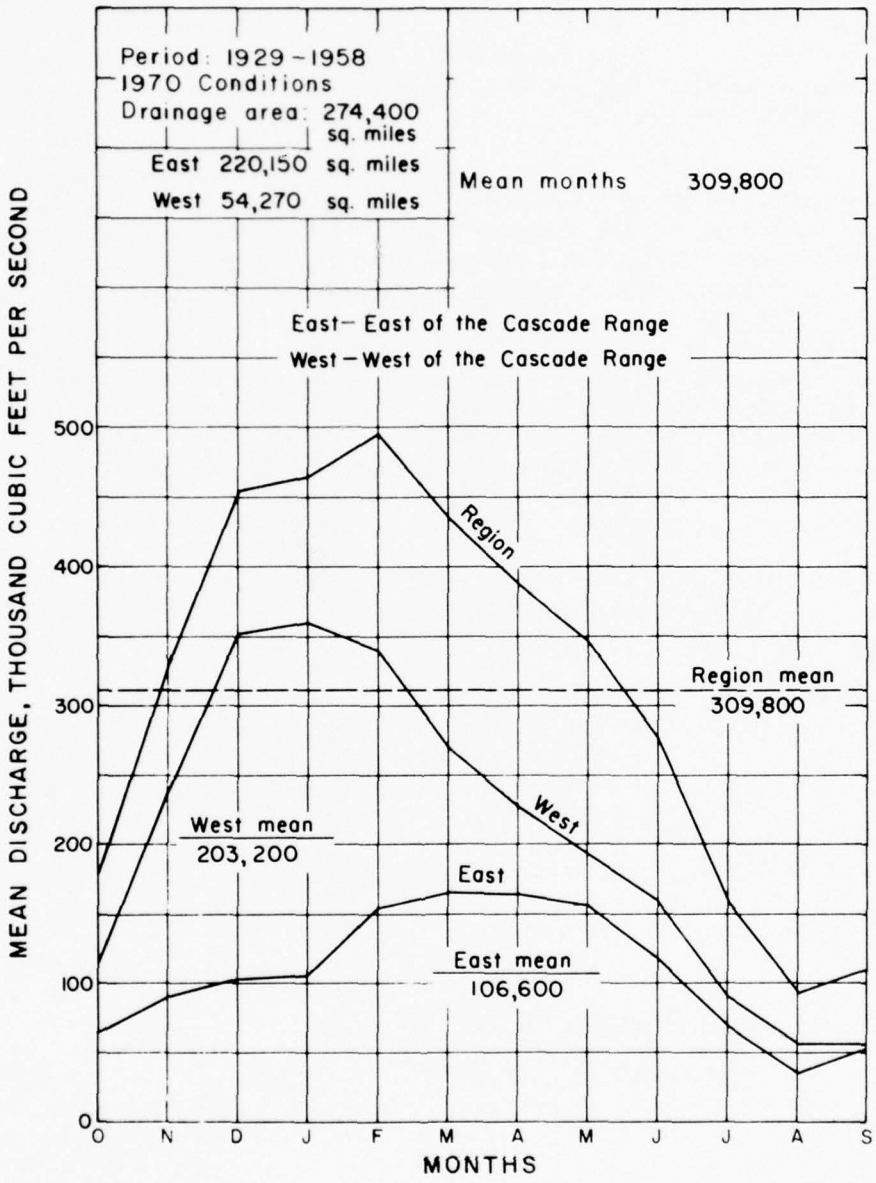


Figure 9. Monthly discharge, Columbia-North Pacific Region (Canada not included)

Table 5 - Selected Sites Where Water Data Have Been Determined

Geological Survey Station No.	Stream and Location	Period of Record
	SUBREGION 1	
12-3000	Kootenay River at Newgate, B.C.	1930-67
3030	Kootenai River at Libby, Mont.	1910-67
3050	Kootenai River at Leonia, Idaho	1928-67
3075	Moyie River at Eileen, Idaho	1925-67
3220	Kootenai River at Porthill, Idaho	1928-67
3400	Blackfoot River near Bonner, Mont.	1939-67 1/
3405	Clark Fork above Missoula, Mont.	1929-67
3530	Clark Fork below Missoula, Mont.	1929-67
3550	Flathead River at Flathead, B.C.	1929-67
3555	Flathead River near Columbia Falls, Mont.	1929-67 1/
3625	South Fork Flathead River near Columbia Falls, Mont.	1928-67 1/
3630	Flathead River at Columbia Falls, Mont.	1928-67
3720	Flathead River near Polson, Mont.	1907-67
3890	Clark Fork near Plains, Mont.	1910-67
3920	Clark Fork at Whitehorse Rapids near Cabinet, Idaho	1928-67
3955	Pend Oreille River at Newport, Wash.	1952-67 1/
3985	Pend Oreille River below Z Canyon near Metaline Falls, Wash.	1912-67 1/
4135	Coeur d'Alene River near Cataldo, Idaho	1920-67 1/
4225	Spokane River at Spokane, Wash.	1891-67
	SUBREGION 2	
12-3995	Columbia River at International Boundary	1937-67
4045	Kettle River near Laurier, Wash.	1929-67
4090	Colville River at Kettle Falls, Wash.	1922-67
4365	Columbia River at Grand Coulee Dam, Wash.	1928-67 1/
4385	Okanagan River at Okanagan Falls, B.C.	1915-65
4425	Similkameen River near Nighthawk, Wash.	1911-67
4450	Okanogan River near Tonasket, Wash.	1929-67
4495	Methow River at Twisp, Wash.	1919-62
4525	Chelan River at Chelan, Wash.	1903-67
4590	Wenatchee River at Peshastin, Wash.	1928-67
4650	Crab Creek at Irby, Wash.	1942-67
4728	Columbia River below Priest Rapids Dam, Wash.	1917-67
	SUBREGION 3	
12-4745	Yakima River near Martin, Wash.	1903-67
4760	Kachess River near Easton, Wash.	1903-67
4790	Cle Elum River near Roslyn, Wash.	1903-67
4795	Yakima River at Cle Elum, Wash.	1906-67
4845	Yakima River at Umtanum, Wash.	1906-67
4880	Bumping River near Nile, Wash.	1909-67 1/
4885	American River near Nile, Wash.	1939-67 1/
4915	Tieton River at Tieton Dam near Naches, Wash.	1925-67 1/
4940	Naches River below Tieton River near Naches, Wash.	1908-67 1/
5005	North Fork Ahtanum Creek near Tampico, Wash.	1907-67
5010	South Fork Ahtanum Creek at Conrad Ranch near Tampico, Wash.	1915-67
5050	Yakima River near Parker, Wash.	1908-67
5105	Yakima River at Kiona, Wash.	1933-67 1/
	SUBREGION 4	
13-110	Snake River at Moran, Wyo.	1903-67
None	Snake River at Wyoming-Idaho line	-
375	Snake River near Heise, Idaho	1910-67
565	Henrys Fork near Rexburg, Idaho	1909-67
685	Blackfoot River near Blackfoot, Idaho	1913-67
755	Portneuf River at Pocatello, Idaho	1911-67 1/
770	Snake River at Neeley, Idaho	1906-67
880	Snake River at Milner, Idaho	1909-67
1270	Big Lost River below Mackay Reservoir near Mackay, Idaho	1919-67 1/
1525	Big Wood River near Gooding, Idaho	1916-67
1545	Snake River at King Hill, Idaho	1909-67
	SUBREGION 5	
13-1685	Bruneau River near Hot Spring, Idaho	1943-67 1/
1830	Owyhee River below Owyhee Dam, Oreg.	1929-67
2020	Boise River near Boise, Idaho	1954-67 1/
2125	Boise River at Notus, Idaho	1920-67
2200	Malheur River at Little Valley near Hope, Oreg.	1949-67 1/
2475	Payette River near Horseshoe Bend, Idaho	1919-67 1/
2510	Payette River near Payette, Idaho	1935-67
2660	Weiser River near Weiser, Idaho	1952-67 1/
2690	Snake River at Weiser, Idaho	1910-67
2730	Burnt River near Hereford, Oreg.	1928-67 1/
2895	Powder River near Robinette, Oreg.	1928-57
2902	Snake River below Pine Creek at Oxbow, Oreg.	1958-67
	SUBREGION 6	
13-2985	Salmon River near Challis, Idaho	1928-67
3025	Salmon River at Salmon, Idaho	1919-67 1/
3150	Salmon River near French Creek, Idaho	1944-56
3170	Salmon River at Whitebird, Idaho	1919-67 1/
3325	Grande Ronde River at Rondowa, Oreg.	1926-67
3365	Selway River near Lowell, Idaho	1929-67 1/
3370	Lochsa River near Lowell, Idaho	1929-67 1/
3390	Clearwater River at Kamiah, Idaho	1910-65
3425	Clearwater River at Spalding, Idaho	1925-67 1/
3435	Snake River near Clarkston, Wash.	1915-67
3510	Palouse River at Hooper, Wash.	1951-67 1/
3530	Snake River below Ice Harbor Dam, Wash.	1962-67 1/
	SUBREGION 7	
None	Walla Walla River near Milton, Oreg. (Oreg.-Wash. border)	-
14-185	Walla Walla River near Touchet, Wash.	1951-67
210	Umatilla River at Pendleton, Oreg.	1934-67 1/
335	Umatilla River near Umatilla, Oreg.	1903-67
345	Willow Creek at Heppner, Oreg.	1951-67
405	John Day River at Picture Gorge near Dayville, Oreg.	1926-67
460	North Fork John Day River at Monument, Oreg.	1925-67

1/ Denotes other short periods of record.

Table 5 - Continued

Geological Survey Station No.	Stream and Location	Period of Record
	SUBREGION 7, Continued	
465	John Day River at Service Creek, Oreg.	1929-67 1/
480	John Day River at McDonald Ferry, Oreg.	1904-67
660	Deschutes River below Lava Island near Bend, Oreg.	1926-65
705	Deschutes River below Bend, Oreg.	1914-67
875	Crooked River near Culver, Oreg.	1917-63
1030	Deschutes River at Moody near Biggs, Oreg.	1906-67 1/
1057	Columbia River at The Dalles, Oreg.	1878-67
1130	Klickitat River near Pitt, Wash.	1928-67 1/
1210	Hood River near Hood River, Oreg.	1913-64
1235	White Salmon River near Underwood, Wash.	1935-67 1/
None	Columbia River at Bonneville Dam, Oreg.	-
	SUBREGION 8	
14-2205	Lewis River at Ariel, Wash.	1923-67
2225	East Fork Lewis River near Heisson, Wash.	1929-67
2265	Cowlitz River at Packwood, Wash.	1929-67 1/
2325	Cispus River near Randall, Wash.	1929-67 1/
2425	Toutle River near Silver Lake, Wash.	1929-67 1/
2430	Cowlitz River at Castle Rock, Wash.	1926-67
2475	Elochoman River near Cathlamet, Wash.	1940-67
None	Columbia River at mouth	-
	SUBREGION 9	
14-1425	Sandy River below Bull Run River, near Bull Run, Oreg.	1929-67 1/
1520	Middle Fork Willamette River at Jasper, Oreg.	1923-67 1/
1575	Coast Fork Willamette River near Goshen, Oreg.	1950-67 1/
1655	McKenzie River near Coburg, Oreg.	1944-67
1700	Long Tom River at Monroe, Oreg.	1927-67 1/
1710	Marys River near Philomath, Oreg.	1940-67
1720	Calapooia River at Holley, Oreg.	1935-67
1740	Willamette River at Albany, Oreg.	1895-67 1/
1815	North Santiam River at Niagara, Oreg.	1938-67 1/
1875	South Santiam River at Waterloo, Oreg.	1923-67 1/
1890	Santiam River at Jefferson, Oreg.	1939-67 1/
1905	Luckiamute River near Suver, Oreg.	1940-67 1/
1910	Willamette River at Salem, Oreg.	1923-67 1/
1940	South Yamhill River near Whiteson, Oreg.	1940-67
2000	Molalla River near Canby, Oreg.	1928-59 1/
2020	Pudding River at Aurora, Oreg.	1928-64
2075	Tualatin River at West Linn, Oreg.	1928-67
2077	Willamette River at Oregon City, Oreg.	-
2100	Clackamas River at Estacada, Oreg.	1908-67
None	Willamette River at mouth	-
	SUBREGION 10	
12-415	Soleduck River near Fairholm, Wash.	1933-67 1/
410	Hoh River near Forks, Wash.	1926-64
395	Quinault River at Quinault Lake, Wash.	1911-67
360	Wynoochee River above Save Creek near Aberdeen, Wash.	1925-67
350	Satsop River near Satsop, Wash.	1929-67

Geological Survey Station No.	Stream and Location	Period of Record
	SUBREGION 10, Continued	
12-275	Chehalis River near Grand Mound, Wash.	1928-67
170	North River near Raymond, Wash.	1927-67
100	Naselle River near Naselle, Wash.	1929-67
14-3010	Nehalem River near Foss, Oreg.	1939-67
3015	Wilson River near Tillamook, Oreg.	1931-67 1/
3055	Siletz River at Siletz, Oreg.	1925-67 1/
3065	Alsea River near Tidewater, Oreg.	1939-67
3120	South Umpqua River near Brockway, Oreg.	1942-67 1/
3135	North Umpqua River below Lemolo Lake, Near Toketee Falls, Oreg.	1927-67
3210	Umpqua River near Elkton, Oreg.	1905-67
3250	South Fork Coquille River at Powers, Oreg.	1928-67 1/
None	South Fork Coquille River near Coquille, Oreg.	-
3390	Rogue River at Dodge Bridge, near Eagle Point, Oreg.	1938-67
3615	Rogue River at Grants Pass, Oreg.	1938-67
3771	Illinois River near Kerby, Oreg.	1961-67
None	Rogue River near Gold Beach, Oreg.	-
	SUBREGION 11	
12-865	Nisqually River at LaGrande, Wash.	1943-67 1/
1780	Skagit River at Newhalem, Wash.	1908-67
1940	Skagit River near Concrete, Wash.	1924-67
1705	Skagit River at International Boundary near Hope, B.C.	1935-55
455	Elwha River at McDonald Bridge, near Port Angeles, Wash.	1918-67 1/
480	Dungeness River near Sequim, Wash.	1937-67 1/
540	Duckabush River near Brinnon, Wash.	1938-67 1/
565	North Fork Skokomish River below Staircase Rapids, near Hoodsport, Wash.	1924-67
970	White River at Greenwater, Wash.	1929-67
1015	Puyallup River at Puyallup, Wash.	1914-67
1130	Green River near Auburn, Wash.	1936-67
1330	South Fork Skykomish River near Index, Wash.	1911-67 1/
1490	Snoqualmie River near Carnation, Wash.	1928-67
1610	South Fork Stillaguamish River near Granite Falls, Wash.	1928-67
1670	North Fork Stillaguamish River near Arlington, Wash.	1928-67
1895	Sauk River near Sauk, Wash.	1928-67
2105	Nooksack River at Deming, Wash.	1935-57 1/
	SUBREGION 12	
10-3715	Deep Creek above Adel, Oreg.	1929-67 1/
3785	Honey Creek near Plush, Oreg.	1930-67 1/
3840	Chewaucan River near Paisley, Oreg.	1924-67 1/
3900	Silver Creek near Silver Lake, Oreg.	1943-67 1/
3935	Silvies River near Burns, Oreg.	1922-67 1/
3960	Donner and Blitzen River near Frenchglen, Oreg.	1938-67 1/
4065	Trout Creek near Denio, Oreg.	1932-67 1/

1/ Denotes other short periods of record.

Explanations of the data common to all subregions are included here rather than being repeated in each subregion section.

Computer programs were written by the Corps of Engineers, North Pacific Division, Portland, Oregon, for use in reducing the monthly discharge data to summary form for plotting many of the graphs. (165)[1/]

Hydrographs of monthly discharges are provided for seven flow conditions: maximum, minimum, and mean monthly flows; the flows that may be expected to occur 20 and 80 percent of the time; and the monthly flows for the maximum year and the minimum year during the base period. A few points on the maximum-year graph usually coincide with the maximum-month graph; the same is true for the minimum-year and minimum-month graphs. The probability of a future annual mean discharge equaling either the mean of the maximum months or the mean of the minimum months is very remote (recurrence interval of several thousand years). For practical purposes, then, the calculated high and low extreme annual mean discharge (based on the maximum and minimum months) shown on the graphs may be considered limiting values. Low-water discharges of probable occurrence for other than 80 percent of the time, such as 90 or 95 percent, may be obtained from curves drawn through plots of the mean (approximately 50 percent), 80 percent, and minimum (considered to be 100 percent) discharges.

The frequency curves of mean discharge show the highest average flow and the lowest average flow for periods of 1, 3, 6, and 12 consecutive months. Where data were available from the Geological Survey digital computer summaries, flows for 7, 30, 90, 183, and 365 consecutive days were used. The curves based on monthly data show slightly higher discharges for the low-flow series and slightly lower discharges for the high-flow series than for the curves based on daily data because a maximum or minimum month usually does not exactly coincide with the minimum or maximum 30-consecutive-day period. The difference between the curves generally is less than 10 percent and either is satisfactory for planning purposes.

The frequency curves of mean discharge can be used directly as volume-frequency curves with minimum computations. For example, the 30-day, 50-year frequency volume in acre-feet is obtained by multiplying the 30-day, 50-year frequency discharge in cfs by 1.98 times 30, or by 59.4. Volumes for other time periods are obtained in the same manner by multiplying the selected discharge by 1.98 times the number of days in the period.

For most streams in the region the discharge-frequency curves have similar shapes indicating that the mean flows for selected periods of time differ throughout the years by fairly consistent

1/ Numbers in parentheses make reference to the bibliography.

quantities. Direct comparisons of flow characteristics may be made between streams whose flows are essentially natural. In a heavily regulated stream, the curves diverge greatly from the usual relationships and reflect mainly the regulation pattern of that particular stream.

Duration curves are provided for two flow conditions, monthly and annual, and where data are readily available for daily flows. A flow-duration curve is a cumulative frequency curve that shows percentage of time specified discharges were equaled or exceeded during a given period, without regard to the sequence of occurrence. For example, the low flows that represent the 95-percent point on the curve may have occurred at any time during the 30-year base period; they may or may not be consecutive days, months, or years.

Frequency curves of annual peak flows are shown for both regulated (as of 1970) and unregulated flows where data are available, otherwise they are shown for the more common condition. The entire period of record is used in defining these curves. The curves were computed by analytical means using the Corp of Engineers' standard method, probability plot. Additional information on flood characteristics will be presented in the Flood Control Appendix.

Dependable yield of the selected river basins is presented in tables for each subregion. The tables show the lowest mean flows for periods of 1 to 10 consecutive years in the 30-year base period and their percentage of the 30-year mean discharge. The minimum year generally is less than 70 percent of the mean, averages 53 percent of the mean, and ranges from a high of 80 percent to a low of 9 percent of the mean. The Columbia River at its mouth, which drains 70 percent of the region's area, shows a minimum-year discharge equal to 53 percent of the mean, a 3-year minimum average of 54 percent, and a 10-year minimum average of only 64 percent. These tables show conclusively that the use of the mean annual discharge to determine the total quantity of water available in a stream for any period less than about one-half the 30-year base period is not realistic, even with carryover storage. The use of the minimum year or some point on the duration curves, such as the 90-percent point, presents a more practical measure of the total quantity of water that could be made available.

Variations in Discharge Each subregion report contains information on long-term variations in streamflow and precipitation applicable to that subregion. In this section, additional information more applicable to the entire region is presented. This includes data from tree-ring studies and from records of streamflow and precipitation collected for long periods of time at selected sites.

One method that has been used to extend precipitation records consists of the measurement of the rates of growth of trees as shown by the width of the annual rings and comparison of those rates with available precipitation records. (121) In the arid regions, the available soil moisture may be the dominant physical factor in tree growth and local precipitation may be the only source of water. Juniper trees cut in 1931 in the Harney Basin, Subregion 12, were used in the tree-ring study along with precipitation records collected at Burns, Oregon, and at the nearby Harney Branch Experiment Station of the U. S. Department of Agriculture. The mean annual precipitation determined for the period 1898-1930 was 8.6 inches at the experiment station. A comparison of the percentage deviation of tree-ring width or tree growth from the normal growth with the corresponding deviation in precipitation for the period 1898-1930 is shown in the upper graph of figure 10. The close resemblance of the two curves is evident. The lower graph of figure 10 shows the deviation in tree-ring growth from 1734 to 1930. This curve is not as irregular as the upper curve because it is based on a weighted 3-year running average. Although the curves cannot be used to determine the precipitation for a particular year, they do show trends suggesting that low precipitation periods occurred from 1755 to 1780, 1825 to 1850, and 1915 to 1930, and that droughts have occurred at about 85-year intervals. There is a statement in the May 1937 Monthly Weather Review that tree-ring studies show the 1917-35 drought to be the most severe in 650 years.

Long-term and seasonal variations in discharge as presented in the subregion discussions are generally greater than those of precipitation, although they result from precipitation. This is true both for the 30-year base period and for the entire period of record. A typical set of annual values representative of the region is presented in figure 11; long-term variations in precipitation are given for Albany, Oregon, and in discharge for Columbia River at The Dalles, Oregon, Willamette River at Albany, Oregon, and Spokane River at Spokane, Washington. Annual precipitation at Albany varied from the mean by a maximum of about 40 percent, which is about average for all precipitation stations; the maximum year was 2.4 times the minimum. For discharge the maximum was 2.6 times the minimum year at The Dalles, 3.2 at Albany, and 3.5 at Spokane.

The outstanding feature of figure 11 is the general correlation among the three hydrographs. However, the year-by-year correlation of precipitation with discharge is poor. Following the great flood of 1894, both precipitation and streamflow exhibit a general decline to 1945, with substantially higher values since then. Because these higher values are generally above the long-term mean, the base period, 1929-58, is quite representative of the entire period of record. In fact, the base period average precipitation at Albany is 97 percent of the long-term average of 41.2 inches, and the base period contains the lowest and two of the five highest yearly values of record.

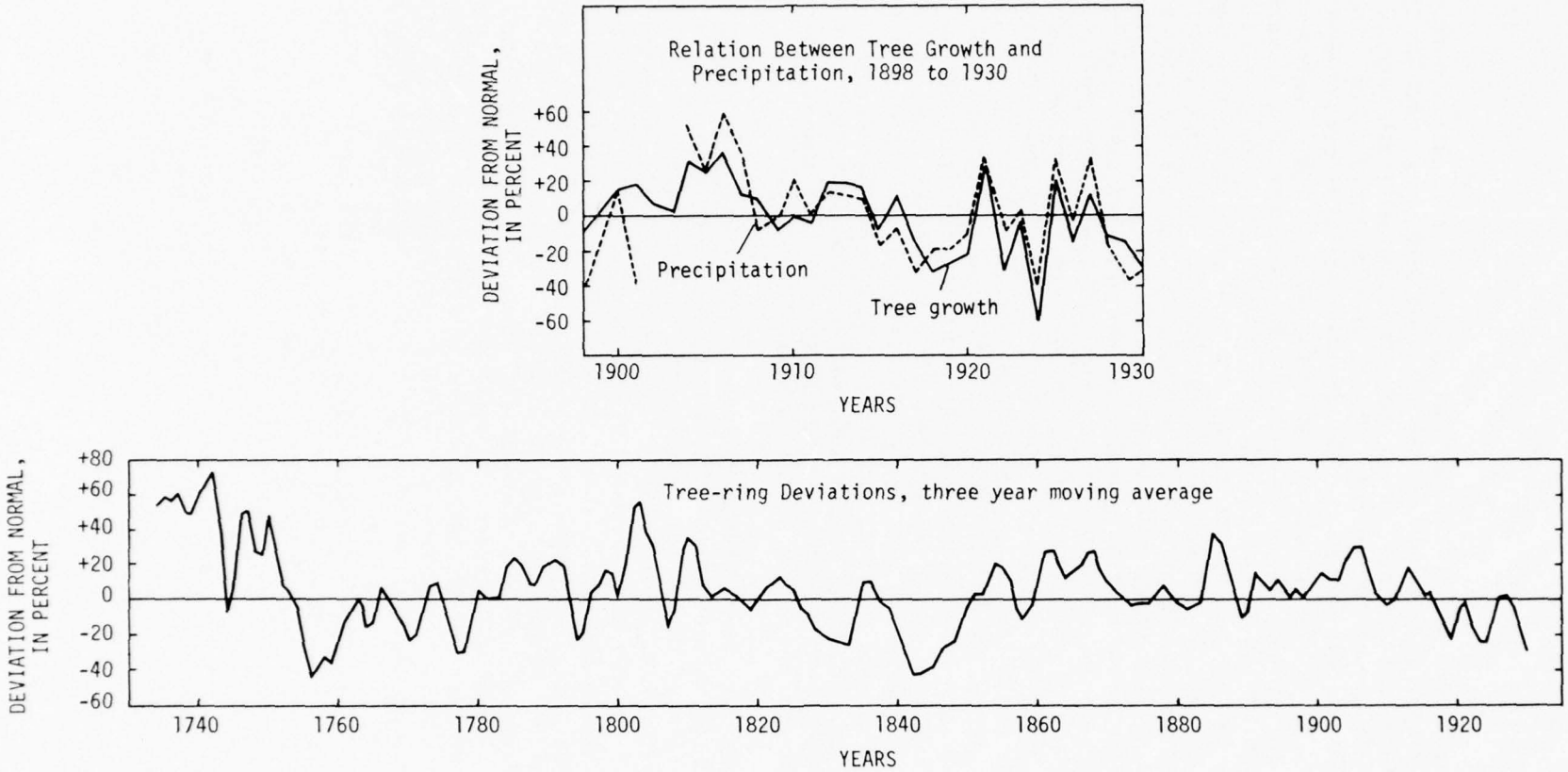


FIGURE 10. General Deviations of Precipitation in the Harney Basin, as Indicated by Tree-ring growth, 1734-1930

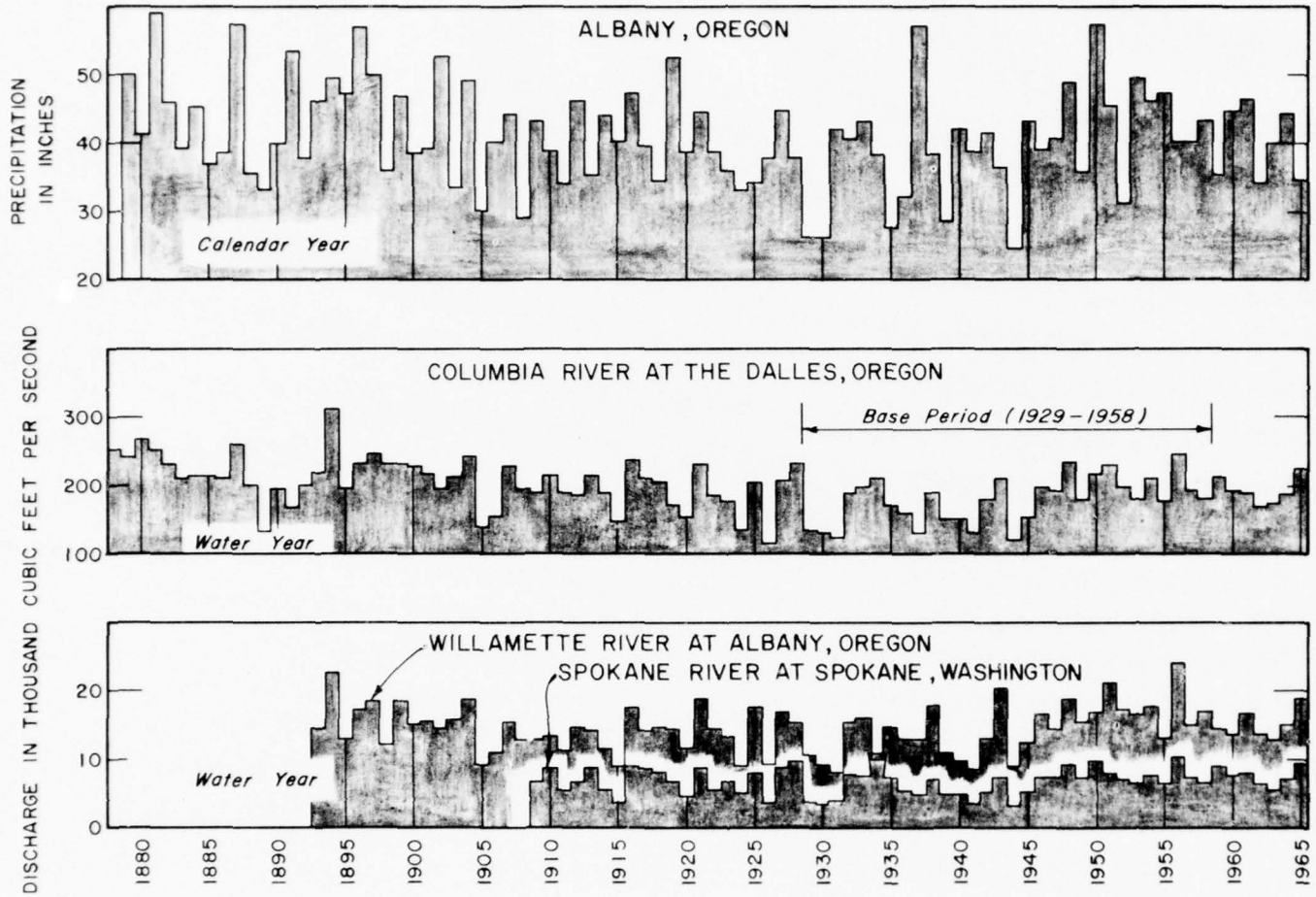


Figure 11. Long – Term Variation in Precipitation and Streamflow.

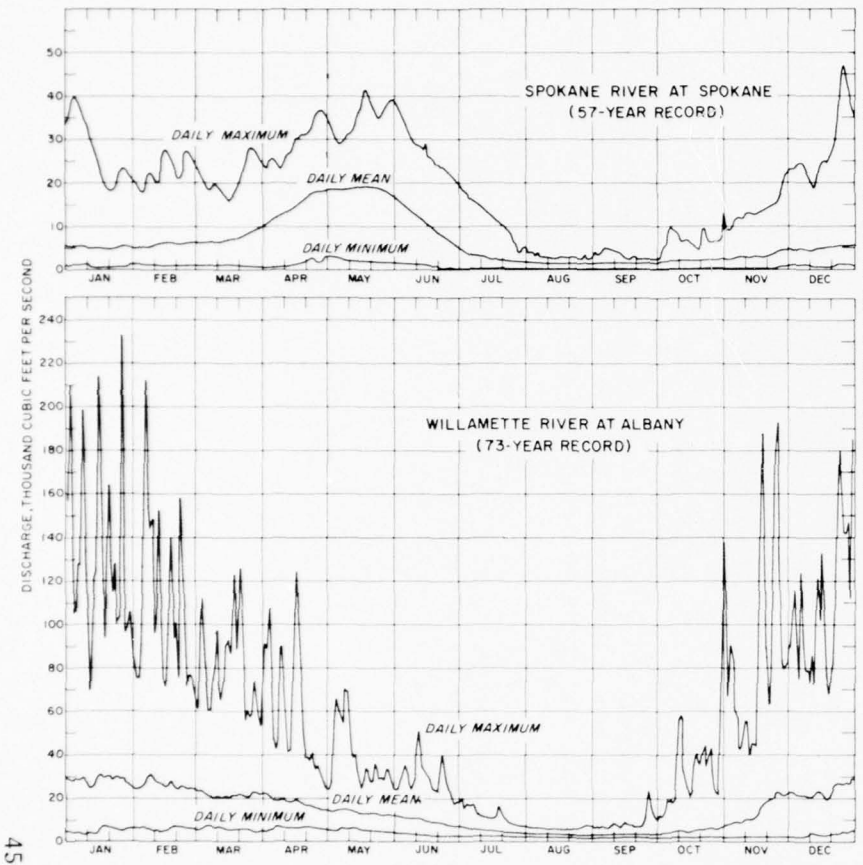
Long-term variations in streamflow can also be compared using slopes of frequency curves and annual duration curves. This was done in the subregion discussions; the greatest slopes, or variations, occurred for the smaller streams of the Mid-Columbia Subregion.

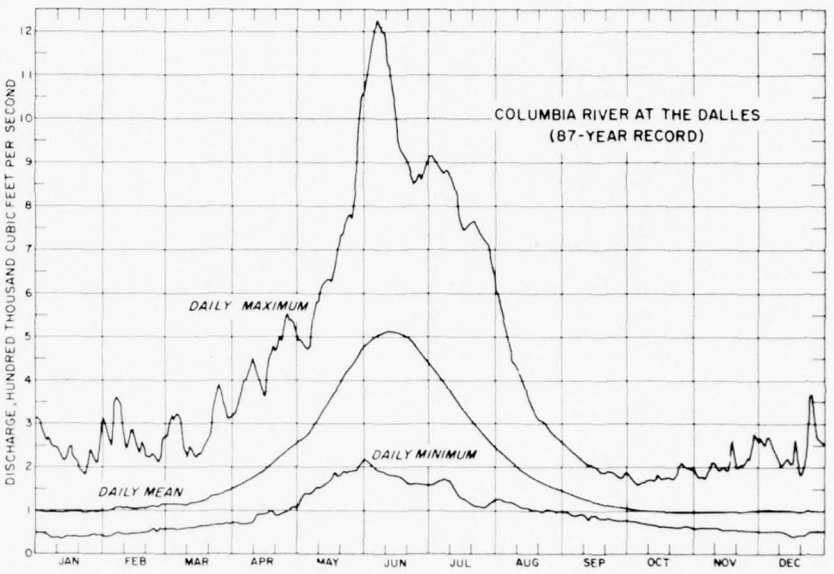
Seasonal variations in discharge are well presented in the monthly hydrographs for each subregion. Daily hydrographs would serve even better but are laborious to construct. Figure 12 is a presentation of summary hydrographs for the three stations, Spokane River at Spokane, Willamette River at Albany, and Columbia River at The Dalles. The maximum, mean, and minimum of daily discharges for each day of the year for all years of record are shown in figure 12. All streamflows are observed values as published in Geological Survey Water-Supply Papers. The average for the period of record is compared with that of modified flows for the 30-year base period, 1929-58, as shown in the notes on figure 12. Of course, during recent years, the effect of storage reservoirs has been to reduce the extreme high and increase the extreme low daily discharges, so that, for conditions as of 1970, the range above and below the mean hydrograph would be reduced. The mean hydrograph itself would be flattened and smoothed.

The hydrograph of the Columbia River clearly indicates snowmelt runoff, with a single protracted peak in June. The Willamette River has its series of rainfall peaks during the winter, and the Spokane River has both the winter peaks and a broad snowmelt high during May. The latter two rivers have their low water during August and September, whereas the Columbia River has its lowest water during October, with very little increase from then until the following April.

The seasonal variations in discharge can also be compared by the spacing between frequency curves of high and low flows. This also is done in the subregion discussions, and again the mid-Columbia tributaries exhibit wide spacing of the frequency curves, or greater change from monthly average to annual average flow. Close spacing is associated with glacial origin deep snowpacks, underground storage, or regulation.

Travel Time Only a few time-of-travel studies of water particles have been made in the Columbia-North Pacific Region. Most of these studies were made by timing the maximum concentrations of Rhodamine B dye as it moved downstream in the river. In some streams, high-, medium-, and low-flow velocities were measured and in others only one flow condition. The results of these studies are shown on graphs in the subregion reports.





NOTES:

1. ALL STREAMFLOWS ARE OBSERVED VALUES PUBLISHED IN U.S. GEOLOGICAL SURVEY WATER SUPPLY PAPERS. THE AVERAGE FLOW FOR THE 87-YEAR PERIOD FOR COLUMBIA RIVER AT THE DALLES IS 194,000 C.F.S. THE AVERAGE OF MODIFIED FLOWS FOR THE 30-YEAR-BASE PERIOD, 1929-58, IS 171,300 C.F.S. COMPARATIVE FIGURES FOR THE WILLAMETTE RIVER AT ALBANY ARE 14,490 C.F.S. (71 YRS.) AND 14,110 C.F.S., RESPECTIVELY. COMPARATIVE FIGURES FOR THE SPOKANE RIVER AT SPOKANE ARE 6,584 C.F.S. (57 YRS.) AND 6,485 C.F.S., RESPECTIVELY.
2. THE 87-YEAR RECORD PERIOD FOR COLUMBIA RIVER AT THE DALLES IS JUNE, 1878 THROUGH SEPTEMBER 1965.
3. THE 73-YEAR RECORD PERIOD FOR WILLAMETTE RIVER AT ALBANY IS NOVEMBER 1892 THROUGH NOVEMBER 1893, JANUARY 1894 THROUGH SEPTEMBER 1894, JANUARY 1895 THROUGH SEPTEMBER 1965.
4. THE 57-YEAR RECORD PERIOD FOR SPOKANE RIVER AT SPOKANE IS JANUARY 1909 THROUGH SEPTEMBER 1965.

FIGURE 12. SUMMARY HYDROGRAPHS

In addition to time-of-travel studies by means of dye injections, studies have been made of flood-wave travel times. The results of these studies appear in the subregion charts as the curve of accumulated hours versus river miles for the highest discharge. Travel times for flood waves have been determined from flood-routing studies as the lag times for the high discharges of the flood hydrograph. For lower flows, flood-wave time and particle time approach equality. To show how the travel time for high flow relates to travel times for lesser flows, a curve has been constructed using the curves for various flows in Subregion 9. (See figure 13, Time of Travel, Willamette River from Albany to Oregon City.)

Figure 13 has a number of interesting characteristics, but the most outstanding is the wide range in flow for a narrow range in travel time. That is, the flood wave travels from Albany to Oregon City in 40 hours or less whether the flow is 30,000 cfs or 280,000 cfs. However, as flow is decreased from 30,000 to 4,000 cfs, the travel time increases from about 40 hours to about 160 hours.

Travel time decreases as discharge increases until the stream overflows its banks. Then, as flows increase, the proportion flowing over rough terrain also increases but requires a longer time at the slower overbank velocity making the average time for the flood wave somewhat greater. The effect of channel storage is also involved; at certain stages of the river there are greater volumes of channel storage to be filled before the water can progress downstream, thus causing increases in travel time.

The travel time for a given reach varies with different floods, even of the same general magnitude. This could depend on whether the flood wave is sharp- or broad-crested, the storm causing the flood occurred near the upper end of the reach or near the lower end, and the antecedent weather conditions in the basin.

The results of these studies have been summarized on figure 14, a map showing flood-wave time of travel for the entire region. The time in hours and distance in miles for a flood wave to travel from a key station to the mouth of the stream are shown for 15 rivers of the region in table 5A.

The best information available on travel time of floods is for the mainstem Willamette and Columbia Rivers as a result of numerous flood-routing studies. The data presented in figure 14 are for flood flows of bankfull magnitude or greater and are general averages for this range. Travel time for the lower portion of the flood hydrograph would be much longer.

As indicated in table 5A and in figure 14, the travel time

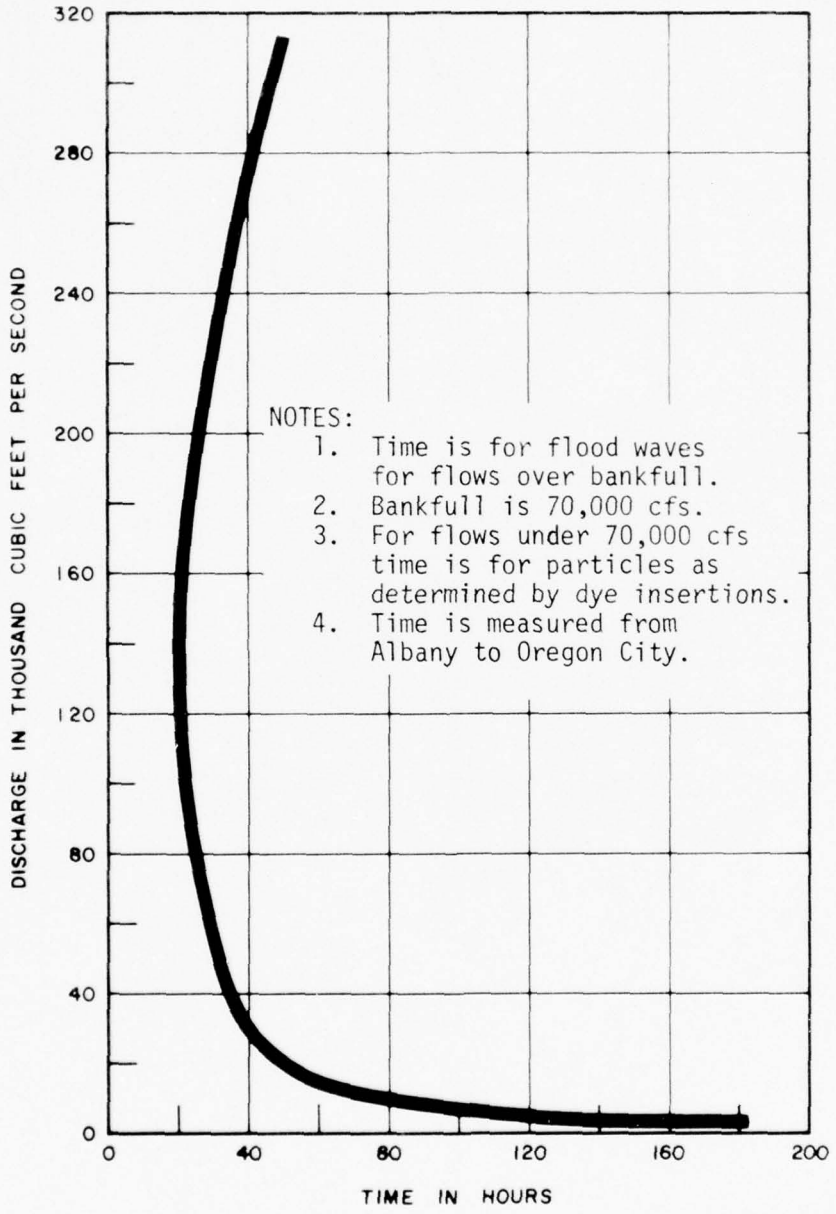


Figure 13. Time of Travel, Willamette River from Albany to Oregon City.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

FLOOD-WAVE TIME OF TRAVEL

THE REGION

1968

FIGURE 14

Table 5A - Time-of-Travel Studies for Rivers at Bankfull, or Higher, Stage, Columbia-North Pacific Region

River	Key Station	Hours	Miles
Chehalis	Grand Mound	40	60
Willamette	Cottage Grove Dam	65	217
Umpqua	Tiller	29	187
Rogue	Prospect	31	171
John Day	Prairie City	60	263
Umatilla	Gibbon	37	79
Walla Walla	Walla Walla City	18	41
Flathead-Pend Oreille	Columbia Falls	410 1/	388
Palouse	Colfax	18	90
Clearwater	Kooskia	40	59
Grande Ronde	La Grande	49	163
Salmon	Challis	85	325
Payette	Cascade Dam	31	113
Snake	Jackson Lake	182	1,000
Columbia	Trail 2/	32	610

1/ Includes 50 in channel, 220 in Flathead Lake, and 140 in Pend Oreille Lake.
2/ To Bonneville Dam.

for the Flathead-Clark Fork-Pend Oreille Rivers is extremely long because of the natural regulation of two lakes. The passage of a flood wave under free-flow conditions through Flathead Lake requires about 9 days and through Pend Oreille Lake about 6 days. Similar long travel times are characteristic of other large lakes in the Columbia River Basin; namely, Coeur d'Alene, Kootenay, and Arrow.

River Profiles River profiles for selected streams in the region are shown in the subregion reports. The Columbia River passes through several subregions and only parts of its profile are available in the subregion reports; therefore, a complete profile from its mouth to the Canadian boundary at river mile 745 has been constructed and is shown in figure 15. This profile shows both the old low-water condition before construction of the many dams as well as the present situation with normal pool elevation for the reservoirs. The river is tide-affected from the mouth, for a distance of 146 miles, to Bonneville Dam; the only other stretch of free-flowing river is the 49-mile reach between Pasco, Washington, and Priest Rapids Dam, river miles 348 to 397.

Snake River also has many dams, and a similar profile shown in figure 16 has been drawn for it.

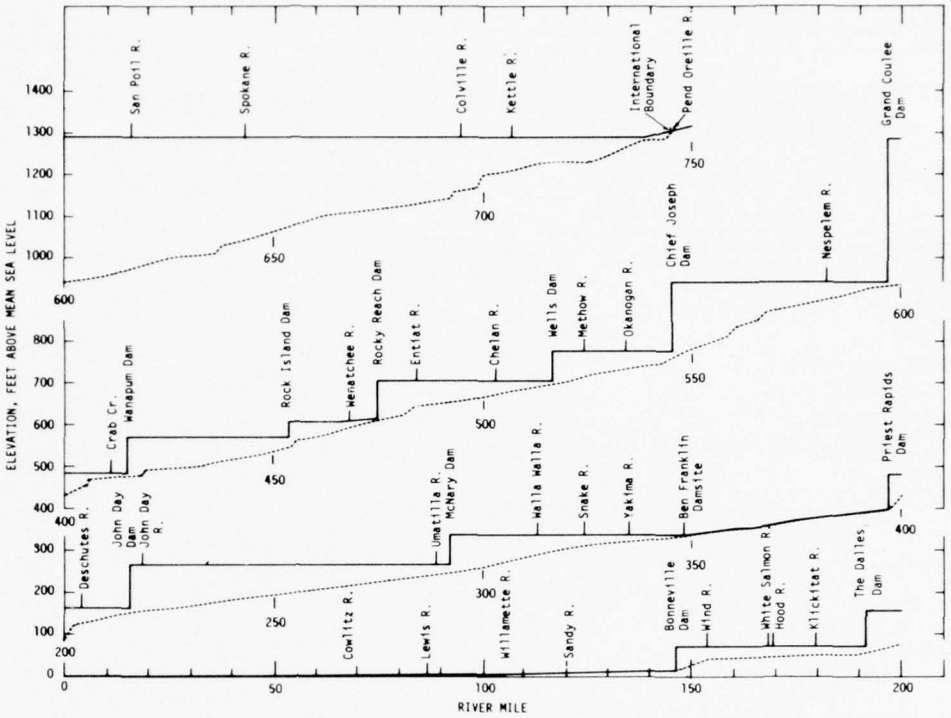


FIGURE 15. Profile of Columbia River From Mouth to Canada Showing Low-Water Profile Before Construction of Dams (----------) and Normal Pool Elevation With Dams (———)

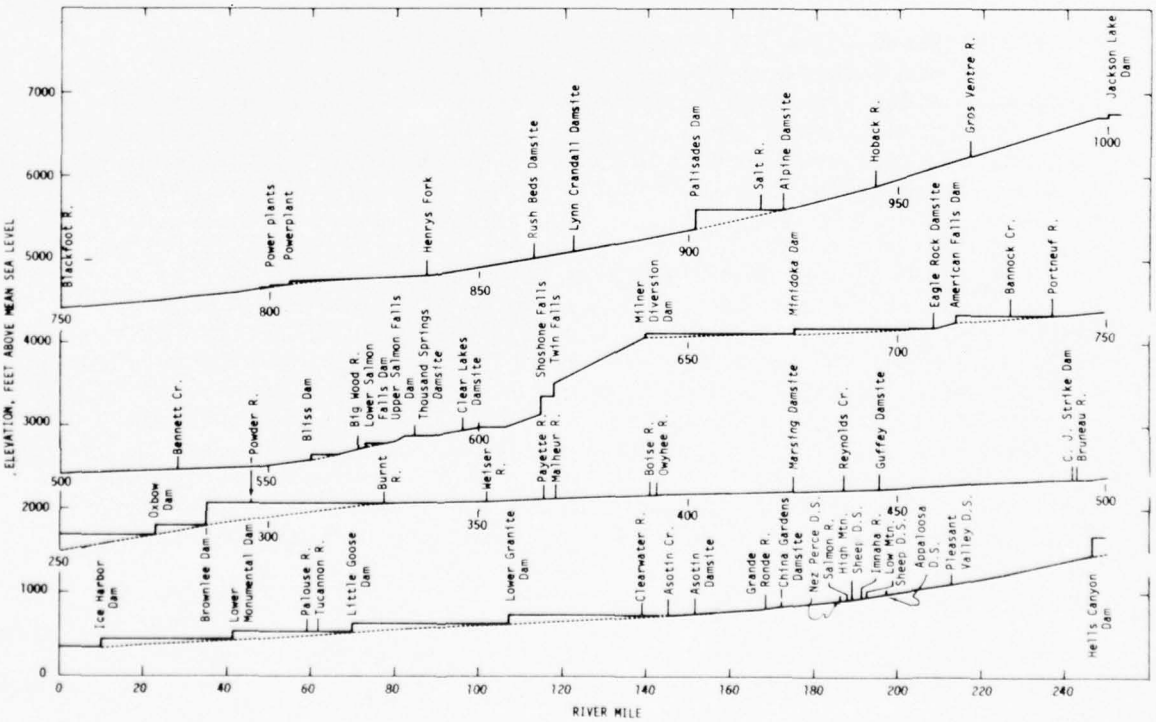


FIGURE 16. Profile of Snake River From Mouth to Jackson Lake Showing Low-Water Profile Before Construction of Dams (----------) and Normal Pool Elevation with Dams (———)

Quality

The quality of surface waters in the Columbia-North Pacific Region is generally good for most uses.

The use of water for domestic purposes alters the biologic quality as well as the chemical and physical quality of the water. Domestic waste consists of metabolic-waste products from man plus waste from ordinary household processes such as dishwashing, laundry, and cooking. These wastes add suspended and dissolved solids to the receiving stream. Conventional sewage treatment can destroy bacteria and reduce the oxygen-consuming substances, but does little toward removing plant nutrients (nitrogen and phosphorous) or destroying detergents contained in domestic-waste water. When treated sewage is discharged to a stream, the nutrients may cause excessive growths of aquatic organisms, which may create taste, odor, and esthetic problems downstream.

Depreciation of water quality by industrial use depends upon the type of industry and even on a particular manufacturing process. The quality of water used for cooling normally is not degraded chemically but is changed physically by raising the temperature. Industries, such as metal fabricating, add small quantities of inorganic chemicals to their waste water while metal-plating industries at times add large amounts. Food-processing industries add considerable quantities of oxygen-consuming organic wastes but small quantities of inorganic chemicals. The pulp and paper industry has created serious pollution problems in many local areas by the discharge of sulfite liquor.

Quality of water may undergo slight to very marked changes as a result of irrigation. The changes depend on soil type, quantity, and quality of water applied, crops grown, fertilizers used, and irrigation practices. In addition, the return-flow water often contains chemicals used for the control of weeds, plant disease, insects, and rodents. The chemical quality of water draining from an irrigated area can be altered in two ways by virtue of its contact with the soil: (1) change in composition by ion exchange, and (2) increase in composition and in the total amount of dissolved solids by leaching of the soil.

The quality of water in the region compares favorably with all other regions in the United States. Table 6, based on work done by F. H. Rainwater (126), shows the percentage of the area of each region where the concentration of dissolved solids was within the specified ranges. Only along the eastern seaboard and the lower Mississippi River is the concentration of dissolved solids less than in the Columbia-North Pacific Region, and then on not more than 1 percent of the area at a level of 350 mg/l (milligrams per liter) or less. According to Rainwater, the prevalent chemical type of

Table 6 - Chemical Quality of Surface Waters in the United States
Dissolved-Solids Concentration

Region	Percent of Regional Area						
	Range of Concentration, mg/l						
	0-100	100-350	350-700	700-1200	1200-1800	1800-2550	2550
Columbia-North Pacific	50.8	47.9	0.1	-	-	-	1.2
South Pacific	32.9	45.7	8.8	10.5	2.1	-	-
Great Basin	-	19.7	32.5	24.2	.9	15.1	7.6
Colorado	3.9	11.2	40.7	38.1	1.9	2.5	1.7
Upper Missouri	3.6	32.8	29.4	19.4	10.6	3.3	.9
Upper Arkansas-Red	1.7	6.4	49.0	18.1	11.2	4.1	9.5
Western Gulf	6.9	36.8	31.1	7.8	10.9	4.4	2.1
Upper Mississippi	18.3	46.0	34.6	1.1	-	-	-
Lower Missouri	-	74.4	25.6	-	-	-	-
Lower Arkansas-Red	36.5	51.4	8.8	3.0	.2	.1	-
Lower Mississippi	72.4	27.6	-	-	-	-	-
Southeast	84.9	14.0	.8	.3	-	-	-
Tennessee-Cumberland	42.1	55.5	1.7	-	.7	-	-
Ohio	20.5	53.3	24.9	.2	1.1	-	-
Western Great Lakes	21.1	74.4	3.3	1.2	-	-	-
Eastern Great Lakes	33.4	50.2	16.4	-	-	-	-
Chesapeake	60.1	36.8	.5	2.5	-	-	-
Delaware-Hudson	55.5	42.6	-	1.9	-	-	-
New England	94.1	5.9	-	-	-	-	-
United States	33.6	38.6	16.2	6.7	2.1	1.6	1.2

water in the Columbia-North Pacific Region is calcium-magnesium carbonate-bicarbonate; about 96 percent of the region contains that kind of water. Nearly two-thirds of the area of the United States has surface water of that type. The next most common type in the country is calcium-magnesium sulfate-chloride which is found in about 22 percent of the area.

Chemical

The concentrations of certain chemical constituents at points in streams throughout the region are shown on maps in the subregion reports. Those concentrations are important in determining the acceptability of the water for use by man. Certain criteria for drinking-water standards have been established by the U. S. Public Health Service. (168-7) These criteria are generally accepted by most state, county, and municipal authorities in determining acceptability of water for drinking. Tables 7 and 8 present some of the recommended limits for drinking water.

Table 7 - Recommended Drinking-Water Standards for Several Constituents and Properties of Water

Constituent or Property	Recommended Maximum Allowable Concentration, in Milligrams per Liter
Iron (Fe)	0.30
Sulfate (SO_4)	250
Chloride (Cl)	250
Nitrate (NO_3)	45
Dissolved Solids	500

Table 8 - Recommended Fluoride Concentrations for Drinking Water

Annual Average of Maximum Daily Air Temperatures (^oF) 1/	Recommended Fluoride Concentration Limits, in Milligrams per Liter		
	Lower	Optimum 2/	Upper
50.0-53.7	0.9	1.2	1.7
53.8-58.3	.8	1.1	1.5
58.4-63.8	.8	1.0	1.3
63.9-70.6	.7	.9	1.2
70.7-79.2	.7	.8	1.0
79.3-90.5	.6	.7	.8

1/ Should be based on more than 5 years of record.
2/ Average concentrations greater than 2 times the optimum values constitute grounds for rejection of the drinking-water supply.

Hardness of water is an important factor for domestic and industrial water use. The Geological Survey has classified hardness of water as calcium carbonate in mg/l, as follows:

0-60 mg/l of hardness, water is soft
61-120 mg/l of hardness, water is moderately hard
121-180 mg/l of hardness, water is hard
More than 180 mg/l of hardness, water is very hard

Industrial water-quality requirements are varied; some of the more common and important ones are listed in table 9. The definition of suitable concentration limits for certain constituents of irrigation water is more uncertain, particularly because tolerances of specific plant types vary considerably. The California Water Pollution Control Board (13-151) has developed a set of

Table 9 - Water Quality Tolerances for Industrial Applications
(Allowable Limits in Milligrams per Liter, Except pH and Color 1/)

Industrial Application	Silica (SiO_2)	Iron (Fe)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved Solids	Hardness as $CaCO_3$	pH	Color
Baking 2/	--	0.2	--	--	--	--	--	10
Boiler Feed:								
0-150 psi	40	--	50	200	500-3000	80	8.0 Minimum	80
151-250	20	--	30	100	500-2500	40	8.4	40
251-400	5	--	5	40	100-1500	10	9.0	5
More than 400	1	--	0	20	50	2	9.6	2
Brewing 2/	50	.1	--	50-70	500-1000	--	6.5-7.0	0-10
Carbonated Beverages 2/	--	.1-.2	--	--	850	200-250	--	5-10
Cooling	--	.5	--	--	--	--	--	50
Food Canning, Freezing 2/	--	.2	--	--	--	--	7.5 min.	--
Ice 2/	10	.1-.2	40-60	--	170-1300	70	--	5
Laundering	--	--	75	--	--	50	6.0-6.8	--
Paper Pulp:								
Unbleached Kraft	100	1.0	--	--	500	200	--	100
Groundwood	50	.3	--	--	500	200	--	30
Bleached Kraft	50	.2	--	--	300	100	--	25
Soda and Sulfate	20	.1	--	--	250	100	--	5
Pine	20	.1	--	--	200	100	--	5
Rayon Pulp:								
Production	25	.05	--	--	100	8	7.8-8.3	5
Manufacture	--	.0	--	--	--	55	--	--
Textiles:								
Wool Scouring	--	1.0	--	--	--	20	--	70
General	--	.25	--	--	--	20	--	20
Dyeing	--	.25	--	--	--	20	--	5-20
Cotton Bandages	--	.2	--	--	--	20	--	5

1/ Data after American Water Works Association, 1950, and California Pollution Control Board, 1952.
2/ Must also conform to U. S. Public Health Service drinking-water standards (1962, p. 7-8).

approximate standards for several common constituents or properties of irrigation water, and some of these data are presented in table 10.

Surface water generally contains less than 250 mg/l of dissolved solids and only in a few small areas does the dissolved-solids content exceed 1,000 mg/l. The streams in the mountainous parts of the region mostly have a dissolved-solids content of less than 100 mg/l and some have less than 50 mg/l. The dissolved-solids content of water in lakes with no outlets ranges from 1,000 to 70,000 mg/l or more. Salt-water intrusion into the Columbia River

Table 10 - Classification of the Chemical Suitability of Water for Irrigation 1/

Class	Specific Conductance, in Micromhos at 25°C	Percent Sodium	Milligrams per Liter: Sulfate (SO_4)	Chloride (Cl)	Dissolved Solids
I 2/	Less than 1,000	Less than 60	Less than 200-500	Less than 70-200	Less than 700
II 3/	500-3,000	60-75	200-1,000	70-600	350-2,100
III 4/	More than 2,500-3,000	More than 70-75	More than 600-1,000	More than 200-600	More than 1,750-2,100

1/ Data modified after California Water Pollution Control Board, 1963, p. 109.
2/ Excellent to good: suitable for most plants under most conditions.
3/ Good to injurious: harmful to some plants under certain soil conditions, climate, farming practices.
4/ Injurious to unsatisfactory: unsuitable under most conditions.

estuary reaches about 23 miles upstream from the mouth. For most streams adjacent to saline water, the extent and degree of salt-water intrusion are not accurately known.

Although irrigation is extensive, most of the streams in the region have a dissolved-solids content of less than 500 mg/l. The chemical composition of the dissolved solids will vary depending upon the soils of the drainage basin, but calcium, magnesium, and bicarbonate are usually the principal constituents. Sodium is a main constituent in some streams tributary to the Snake River.

Biological-Biochemical

Large quantities of relatively unpolluted water are available; however, significant water-quality problems do exist locally in various parts of the region. Water for drinking and certain industrial uses requires disinfection--a standard procedure throughout the United States.

The requirements of the salmonoid fishery govern the necessary level of dissolved oxygen for most watercourses in the region. Northwest States' water-quality standards for dissolved-oxygen levels normally range from 5 mg/l for fish passage needs up to saturation for waters used for spawning and rearing purposes. Low dissolved-oxygen concentrations occur in a number of stream reaches normally as the result of heavy biochemical oxygen demand exerted by municipal, pulp and paper, or food-processing wastes. For example, critical oxygen problems exist seasonally in the Spokane River at and below Long Lake, in portions of the Snake River, and in the lower reaches of the Boise, Duwamish, Chehalis, South Santiam, Tualatin, and Willamette Rivers.

Bacterial pollution resulting from municipal wastes and, in some places, from animal populations has seriously damaged use for water-contact sports in a number of locations. The lower Willamette River and the Columbia River below Portland generally have bacterial counts above the water-quality standard of 1,000 organisms per 100 milliliters which applies to these stream reaches. Similar conditions are prevalent below large population centers in the lower reaches of numerous streams, including the Rogue, South Umpqua, and Boise Rivers, and a number of Puget Sound streams. Some coastal waters, such as Tillamook Bay and Port Angeles Harbor, are similarly affected. The problem is serious because it generally occurs close to urban areas where the demand for water-based recreation is highest.

Nutrients, such as nitrate and phosphate, originating from both natural and manmade sources, are the major cause of excessive aquatic growths in the Yakima and Snake Basins and areas of the

Columbia Basin Irrigation Project. In addition to causing taste and odor problems, such growths increase maintenance costs to irrigators because of clogged diversion and distribution structures. Intensive algal growths cause extreme diurnal fluctuations in dissolved-oxygen concentrations in some streams and in reservoirs, such as Brownlee. A recent fish kill in American Falls Reservoir has been attributed to low dissolved-oxygen concentrations resulting from decomposition of dead algal cells. Other nutrients, derived principally from pulp and paper wastes, have contributed to the periodic slime problem in the lower Columbia River. Fouling of sport and commercial fishing gear has resulted from the slime growths.

Conversely, some streams have been rendered biologically sterile and nonproductive because of acid mine wastes. This type of problem occurs in reaches of streams such as the South Fork, Coeur d'Alene, and Clark Fork Rivers. The wastes discharged to the Pend Oreille River are from tailings from lead and zinc milling operations; and their effect on the river is primarily solids, turbidity, and sediment, and, to some extent, zinc.

Sediment

The areas of greatest sediment yield in the region are the windblown-soil areas in the Palouse and Walla Walla River Basins of southeastern Washington. There is a considerable range in the quantity of fluvial sediment transported by the remaining streams.

Sediment yield of lands east of the Cascade Range ranges from 0.02 to 4.0 acre-feet per square mile per year, with more than one-half the area in the range of 0.02 to 0.1 acre-foot per square mile per year. Only a few rather small areas yield more than 0.5 acre-foot per square mile per year. On the west side of the Cascade Range, most of the area lies in the 0.1 to 0.2 acre-foot per square mile per year yield range, with only small local areas ranging up to 0.5 or down to 0.02 acre-foot per square mile per year. The yields which are delineated on maps in each of the subregion reports are based on data that include both suspended sediment and bedload.

Streams draining the more arid parts of the region, as a general rule, transport higher concentrations of fluvial sediment than those draining the humid, forested parts. However, on an annual basis, more sediment may be transported out of the forested areas because of more frequent storms and larger volumes of water. Streams originating from glaciers transport rock material called "glacial flour" during the summer months, while those whose low flow is derived from ground water generally remain relatively free of fluvial sediment in summer. Sediment concentrations as high as 383,000 mg/l have been measured in the high-yield area near Walla

Walla, Washington. The maps in the subregion reports include information on the location of sites where high-sediment concentrations have been measured.

Temperature

Temperature changes in bodies or streams of water may result from natural climatic phenomena or from the introduction of industrial wastes or discharges of cooling waters. The temperature is sometimes critical for many uses of water. It affects the palatability, some treatment processes, and the value for many industrial uses including cooling, and powerfully influences its suitability as a habitat for aquatic life. Additional heat may contribute to undesirable stream conditions such as decreased oxygen capacity, increased oxygen demand, anaerobic zones, putrification of sludge deposits, and the growth of sewage fungi. Stream temperatures may also be increased by irrigation practices and the return of agricultural drainage water. (155)

Natural water temperature is closely related to climate and air temperature. Maximum water temperatures tend to be higher and minimum temperatures lower in streams east of the Cascade Range than in the coastal streams. Figure 17 shows monthly minimum and maximum water temperatures for selected streams. Other more detailed water-temperature data are shown in the subregion reports. Figure 18 shows a time-distribution curve for water temperatures of the Columbia River near The Dalles, Oregon. Some of these temperatures (1952-59) were measured at the old Maryhill Ferry at river mile 210.3; from 1960 to 1966 they were measured at The Dalles Dam at river mile 191.5. The determinations were made once daily and are considered equivalent at the two sites. The maximum water temperature observed at Maryhill Ferry was 81°F., but 97 percent of the time the water temperature was less than 70°F. The water temperature was higher than 70°F. on 100 days during the 15-year period 1952-66. During the month of August 1958, the water temperature ranged from 71° to 81°F., averaging 75°F.

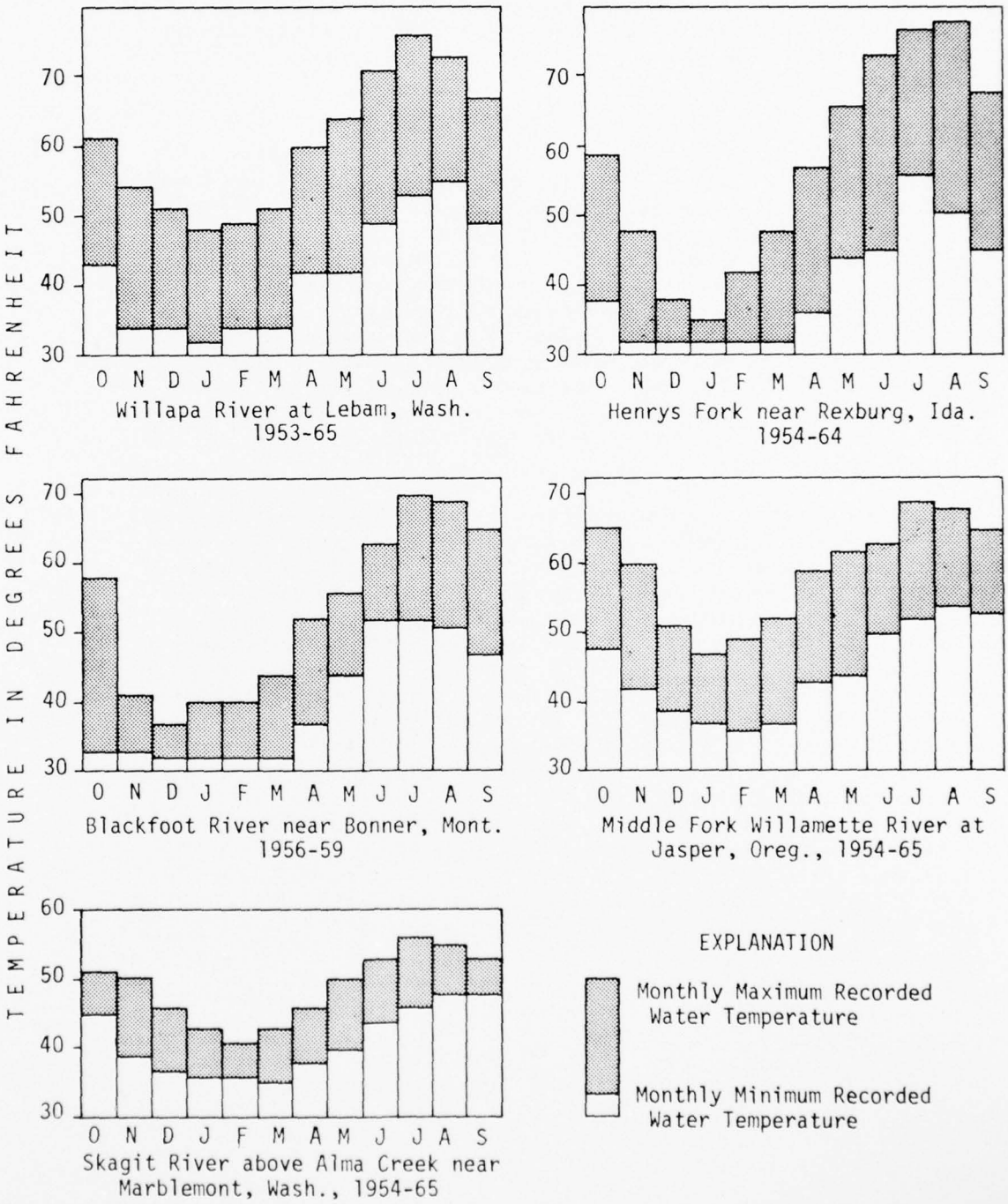


FIGURE 17. Ranges in Temperature of Water in Selected Streams for Periods Indicated

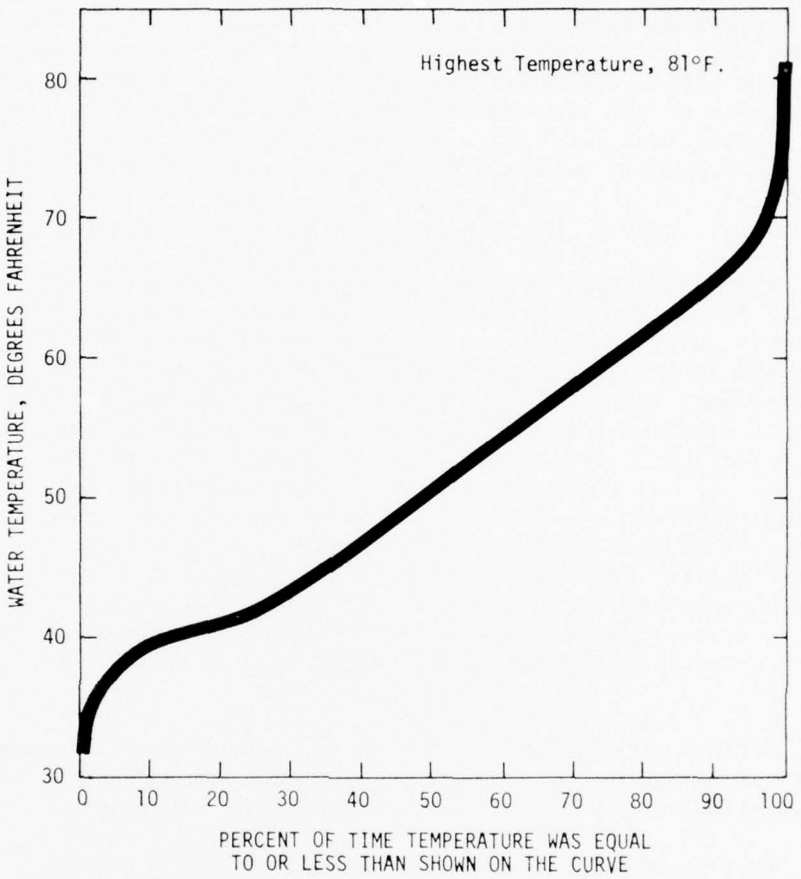


FIGURE 18. Distribution of Water Temperatures, Columbia River near The Dalles, Oreg., 1952-66
(Once Daily Readings.)

Suitability

Chemical Almost all the water in the Columbia-North Pacific Region is chemically suitable for domestic use. Most surface water is soft to moderately hard with a dissolved-solids content of usually less then 500 mg/l. Streams that have a dissolved-solids content of more than 1,000 mg/l are the Malheur and Owyhee Rivers in eastern Oregon, and the Raft River in southern Idaho. The higher concentrations usually are found in the lower reaches of those streams during the summer months when irrigation applications are the greatest. Practically all the water is suitable for irrigation and in many areas irrigation return flows are reused for irrigation without harmful effect.

Surface waters in the region can be used by most industries. Those industries requiring low concentrations of silica would need to treat much of the water because many of the streams contain water with silica concentrations greater than 10 mg/l. In general, because most of the streams contain dissolved oxygen in concentrations greater than 7.0 mg/l, inorganic iron in solution is usually less than 0.2 mg/l, making treatment unnecessary for most industrial uses.

Biological-Biochemical Dissolved-oxygen levels are at or near the saturation point in nearly all fresh and marine waters in the region and the waters are suitable for all uses. However, oxygen levels are depressed in a few bays, estuaries, and lower-river reaches, especially during the summer and early fall as a result of the discharge of large quantities of partly treated or untreated wastes. Dissolved-oxygen concentrations range downward to almost zero at times in certain streams and lakes, well within the classification of septicity. Values below 6 mg/l are considered detrimental to fish life and values below 3 mg/l extremely harmful to aquatic life. Dissolved-oxygen concentrations as low as 0.6 mg/l have been measured in Portland Harbor (lower Willamette River) in recent years. Values below 2.0 mg/l have been measured in Duwamish River near Seattle and values below 3.0 mg/l in Spokane River at Long Lake.

Because the surface waters in the region generally contain a high dissolved-oxygen content, deaeration would be required for any industrial use where corrosion control is a factor.

Most streams in the region can be used for swimming, boating, fishing, and other recreational uses with little hazard from pathogenic (disease-producing) bacteria. In reaches where pathogenic bacteria are a problem, bacteriological quality usually shows very marked and abrupt changes, primarily as a function of sewage disposal. In stream channels below the points where cities discharge untreated sewage, the mpn (most probable number) of coliform bacteria often exceeds 100,000 per 100 milliliters. This means that a stream is point loaded with coliform bacteria. If no downstream-sewage or organic-waste discharge takes place, pollution concentrations will usually be reduced by dilution and natural ecologic processes.

Major streams with known occurrences of serious bacteriological pollution (maximum mpn values greater than 10,000 coliform bacteria per 100 milliliters) are: Snake River upstream from Payette, Idaho; Clark Fork River at Missoula, Montana; Spokane River downstream from Coeur d'Alene, Idaho; Yakima River downstream from Ellensburg, Washington, Willamette River downstream from Eugene, Oregon; Columbia River downstream from Portland, Oregon; and near the mouths of several of the larger streams entering the east and

south sides of Puget Sound. Bacterial pollution in these streams is not always at such high levels. During most of the year streamflow is sufficient to dilute discharged sewage to a much lower level. Maximum values generally occur during the dry summer months when streamflow is low.

Sediment Many streams moving relatively small quantities of sediment may be turbid during the higher flow periods. Industries requiring water with very low concentrations of fluvial sediment or turbidity would have to treat, at some time during the year, almost all surface waters in the region. Because water with sediment concentrations greater than 10 mg/l is considered not potable, cities using surface waters must, at times, either treat their water or use a substitute source, such as wells, as does the city of Tacoma, Washington.

Virtually all waters are satisfactory for irrigation although, at times, sediment may fill siltation basins and necessitate cleaning of the basins. Siltation of major reservoirs generally is not a problem. Sediment concentrations in the Columbia River are small because of the large volume of water, but navigation channels become silted and must be dredged regularly.

Sediment carried by runoff during high flows is damaging to lands particularly during cloudburst floods east of the Cascade Range. In some areas thick deposits of sediment have buried orchards and impaired soils on other farmlands.

Temperature Stream temperatures west of the Cascade Range in the Columbia-North Pacific Region normally do not exceed 70°F. and rarely exceed 80°F.; east of the Cascade Range water temperatures often exceed 80°F. but rarely exceed 90°F. even after being used by man. July and August produce the highest water temperatures. Most streams head high in the mountains and begin their trip to the sea with cold water. In summer, stream temperatures normally increase in a downstream direction owing mainly to solar radiation on the many reservoirs and the generally exposed valley-floor stream channels.

For drinking purposes, water with a temperature of 50°F. is usually satisfactory, temperatures above 59°F. are usually objectionable, and temperatures above 66°F. cause complaints from most customers. (13-283) Also, increased temperatures may stimulate the growth of taste- and odor-producing organisms in lakes and impoundments. Water passing slowly through or standing in swamps may acquire undesirable color and temperature.

Water temperature may be the most important factor for various

industrial uses of water; for example, in steel mills water must have a temperature of less than 75°F., and for barley-malting purposes the temperature should be a uniform 54°F. (13-284) Streams lose their value for cooling purposes as the water temperature rises. Also, warm water accelerates corrosion in pipelines and cooling systems.

Little knowledge is available to indicate the effect of warm irrigation water on crops. However, ground waters of 100° to 180°F. are being used for irrigation in southwestern Idaho but only after being cooled generally to temperatures of 75° to 85°F. by ponding or other means. Water weeds grow sparsely in water below 50°F. but are prolific in 60°F. and warmer water.

The preferred water temperature for rate of growth and production for trout and salmon ranges from 55° to 68°F. Water temperatures of 75° to 77°F. are lethal for adult fish in this group, but some other fishes can tolerate temperatures up to 100°F. Much lower temperatures are required for spawning and hatching of eggs. For example, Chinook salmon eggs fare well at 60°F. but suffer mortalities at 65°F. (13-284)

Sudden changes in temperature are believed to be harmful to fish life, with abrupt changes of 9°F. or greater likely to be injurious.

Many of the streams, especially those east of the Cascade Range, are too warm for some uses during the summer months. Only in the mountains is the water cool enough to be suitable for all purposes at all times of the year.

GROUND WATER

Ground water is an essential element in the appraisal of the water resources of the region. Not only are large quantities of water for a variety of uses obtained from wells and springs, but also a large part of the surface-water supply is maintained by discharge from aquifers, especially during periods of fair weather when the flow of many streams is composed mostly or entirely of effluent ground water.

Caution should be observed, however, by anyone attempting to derive a figure for total perennial yield for the region or for any subregion. Only in coastal areas does any significant quantity of ground water (excluding evapotranspiration) leave the subregion that does not appear as a component of stream discharge. Thus, the values for annual surface-water discharge given for each subregion include the entire ground-water component, except in Subregions 10 and 11 where a part of the ground water discharges directly into

the Pacific Ocean or Puget Sound. In all other subregions, use of ground water as a source of supply does not add to the total available supply except to the extent that ground water is taken from permanent storage, or to the extent that ground-water withdrawals reduce evapotranspiration waste. The latter factor is important and may add large quantities of water to the total available supply at many places.

Although utilization of ground water does not add to the total available supply, with the exceptions noted above, it does offer great opportunities for management by augmenting minimum flows and increasing firm supplies by drawing water from underground storage during dry periods and replacing the ground water by natural or artificial recharge during periods of excess rainfall and runoff.

Much information on ground water is given in published reports and a great amount of data is contained in the files of Federal and State agencies. Published reports are referenced in the text and areas covered by ground-water reports are shown in figure 19.

Relation of Ground Water to Geology

Climate, physiography, drainage, geology, and many other factors strongly influence the occurrence of ground water. The geology probably has a greater effect upon the quantity and quality of water available at any particular point than any other factor. Water-bearing units--aquifers--are geologic formations, groups of formations, or parts of formations. In a study as broad as the Columbia-North Pacific, it is not possible to describe every individual aquifer, even if the required information were available, and for large areas only sketchy data are available. Therefore, geologic formations with similar hydrologic characteristics are grouped into aquifer units.

Geologic formations are mapped on the basis of relative age and type of rock such as sedimentary, volcanic, igneous intrusive, and metamorphic. In the Columbia-North Pacific Region the better yielding aquifers are of two rock types, sedimentary or volcanic. These rocks are layered, and a geologic formation as mapped by the geologist almost invariably includes many layers covering a wide range in permeability. Depending upon the formation, the range may

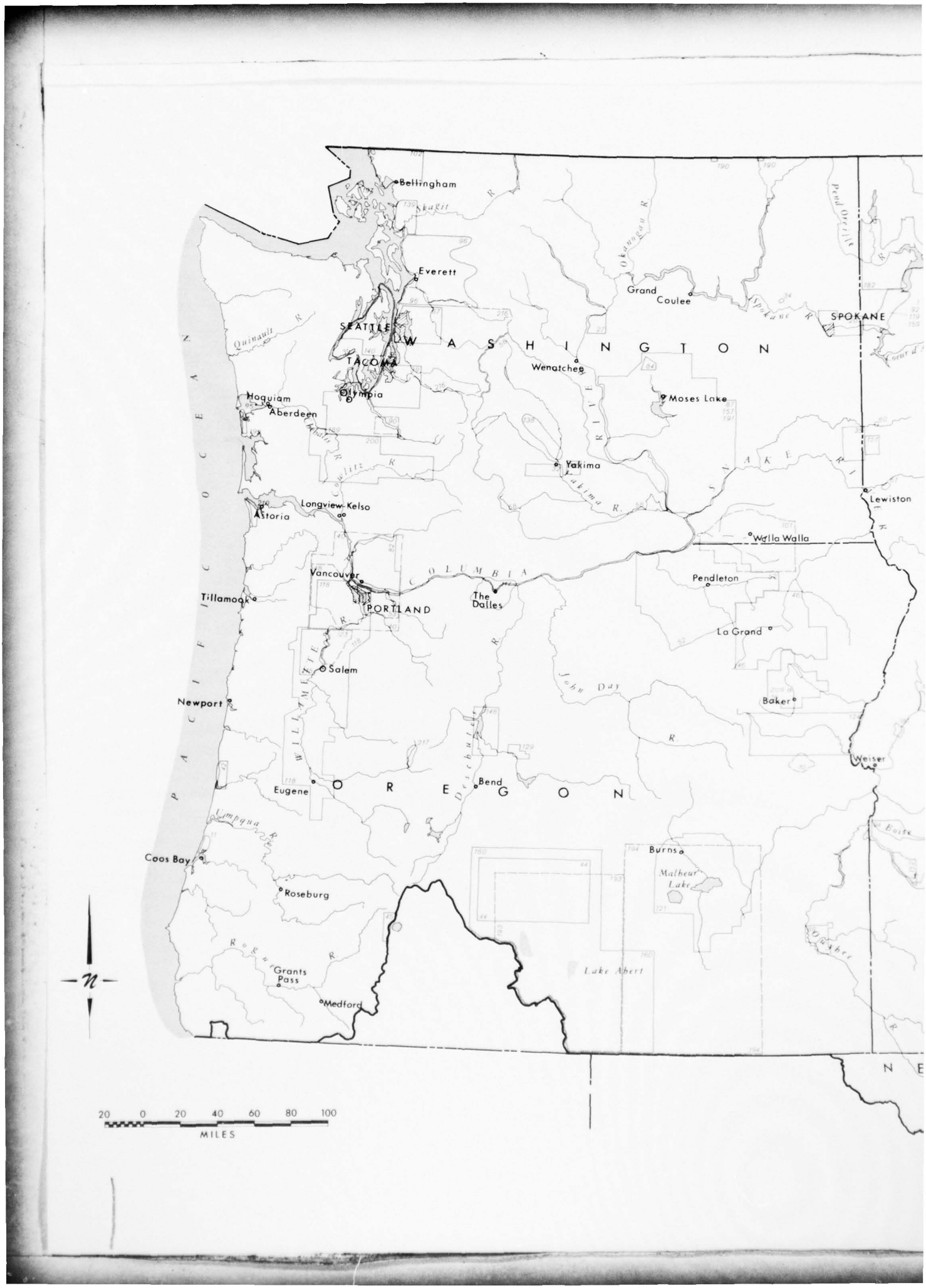
be from highly or moderately permeable to slightly permeable or almost completely impermeable. Commonly, the individual layers or horizons are a few to a few tens of feet thick, and a well may encounter several or a score of permeable and impermeable horizons in a single formation. An aquifer is characterized in this report upon the basis of its more permeable horizons. For example, more than 50 percent of the strata might be clay or silt but, if permeable sand or gravel strata are widespread in the aquifer, then it would be considered to be a permeable aquifer.

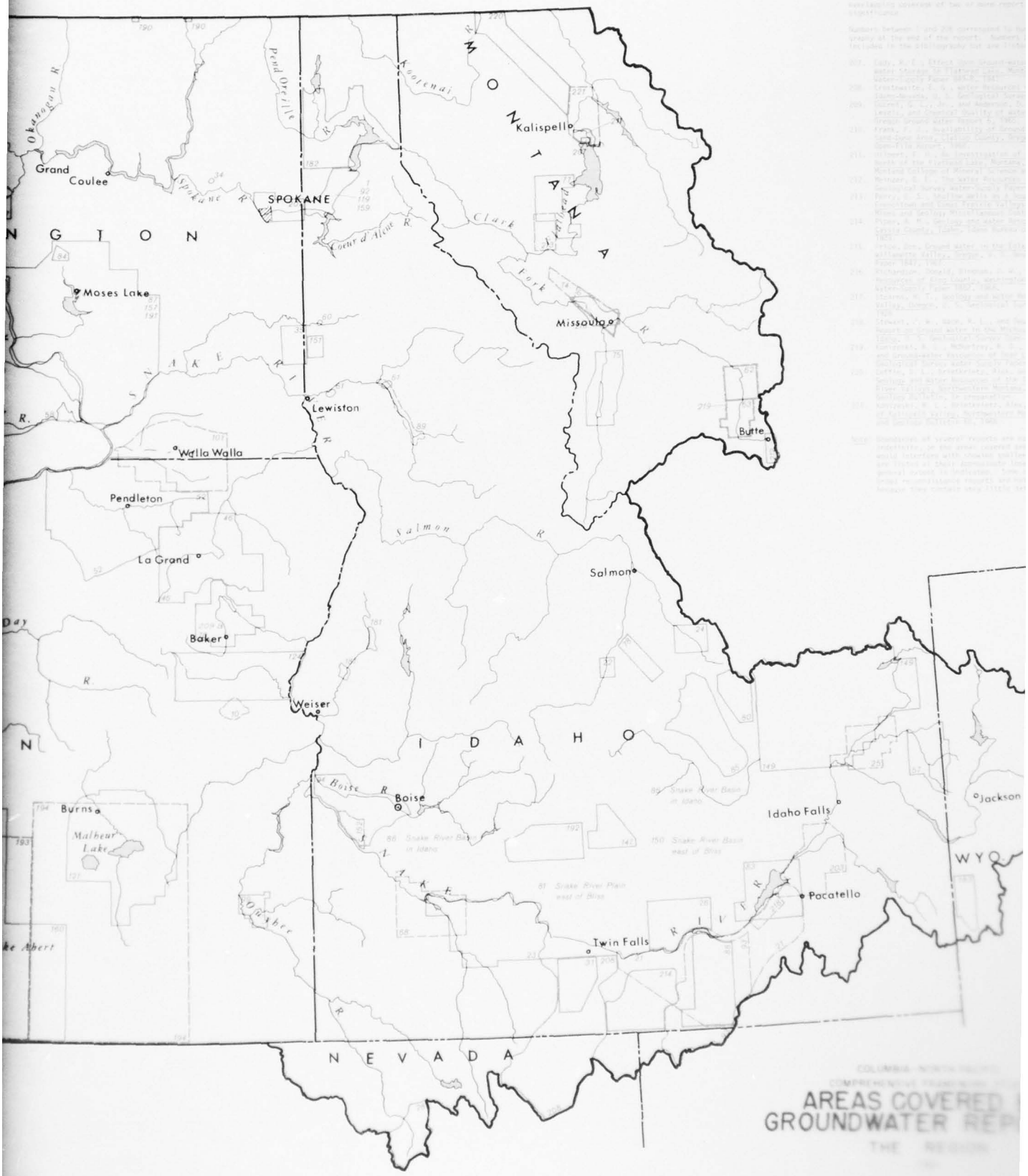
The permeability and porosity of aquifers generally tend to be inversely proportional to their relative ages. Therefore, the distinction between aquifer units is based on both relative age and rock type.

Well Yields

Throughout this report aquifers and aquifer units are characterized quantitatively on the basis of the discharge that can be obtained from a well.

The usual range in yields of wells that can be obtained from each aquifer unit is given in the table describing aquifer units and their hydrologic characteristics that is included in each subregion report. In general, the yield of a well increases with an increase in the thickness of the saturated material and thus is related to well depth. Yields also are related to drawdown. Therefore, the yields given are for well depths and drawdowns generally considered as economically feasible in the area. In alluvial and unconsolidated sedimentary aquifers, where casing and screens are required, the yields given are for wells that have been constructed and developed in accordance with accepted good practices and procedures. In alluvial aquifers, which in places are thin, the yields may be closely related to the saturated thickness of the aquifer. Because of differences in thickness and lateral changes in permeability, the yields of wells in any aquifer unit vary greatly. An attempt was made to select a range so that roughly 80 to 90 percent of the properly constructed wells would fall within it; 5 to 10 percent might have higher, and 5 to 10 percent might have lower yields.

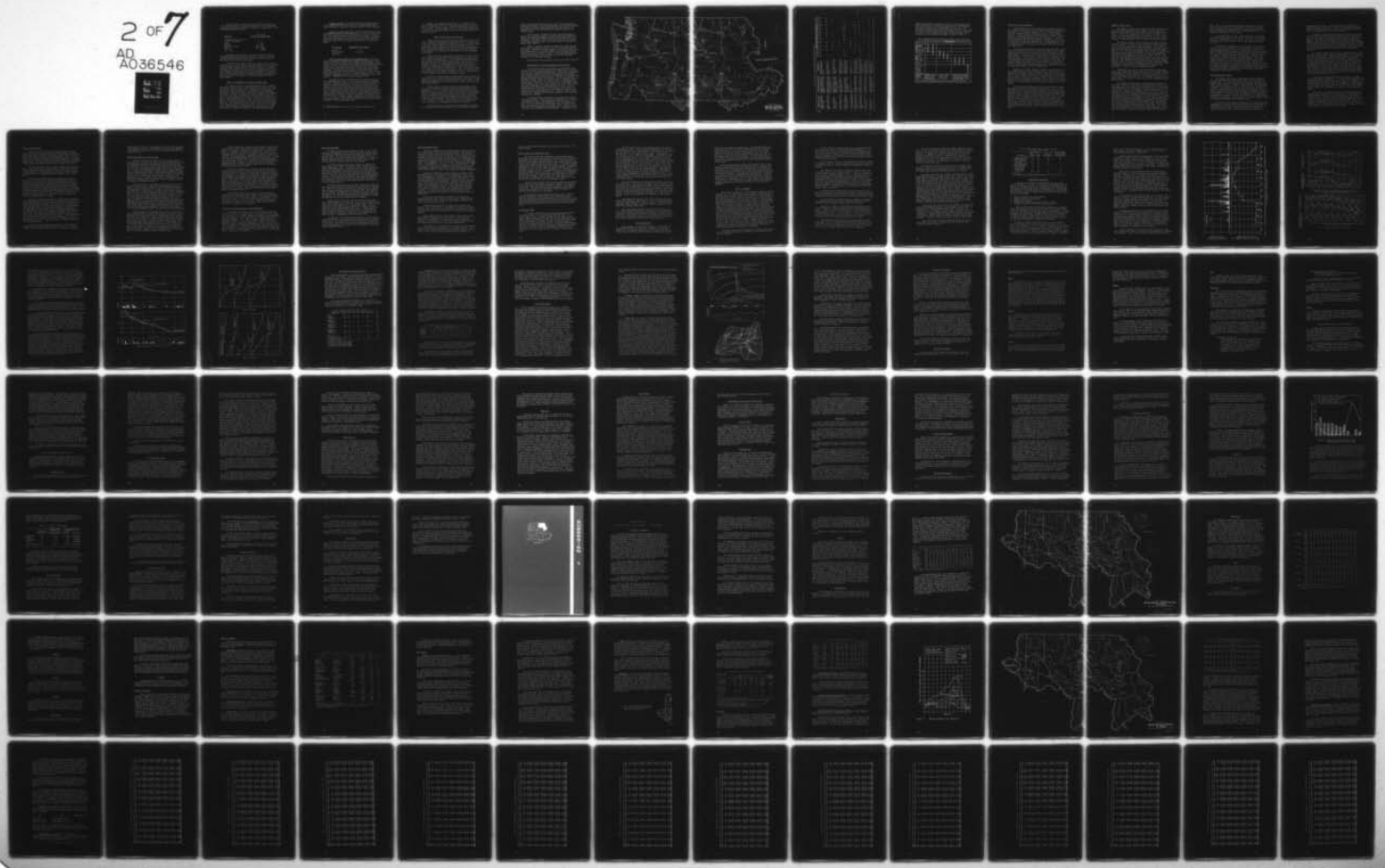

Bellingham
Everett
SEATTLE
TACOMA
Olympia
Hoquiam
Aberdeen
Quinault R
Chehalis R
Satsop R
Wynoochee R
Skagit R
Grand Coulee
Okanogan R
Pend Oreille R
Spokane R
SPOKANE
WASHINGTON
Wenatchee
Moses Lake
Yakima
Yakima R
Columbia River
Lake Roosevelt
Lewiston
Walla Walla
Pendleton
La Grand
Baker
Weiser
Snake R
Longview-Kelso
Astoria
Vancouver
PORTLAND
Columbia R
The Dalles
Tillamook
Willamette R
Salem
John Day R
Newport
Eugene
Deschutes R
Bend
OREGON
Umpqua R
Coos Bay
Roseburg
Rogue R
Grants Pass
Medford
Burns
Malheur Lake
Lake Abert
Owyhee R
Pacific Ocean
N
20 0 20 40 60 80 100
MILES


Okanogan R.
Grand Coulee
Pend Oreille R.
Kootenai R.
Kalispell
SPOKANE
Spokane R.
Coeur d'Alene R.
Clark Fork
Flathead R.
Moses Lake
Missoula
Lewiston
Butte
Walla Walla
Pendleton
Salmon R.
La Grand
Salmon
Baker
Weiser
Boise R.
Boise
Burns
Malheur Lake
Idaho Falls
Jackson
Pocatello
Twin Falls
Owyhee R.
NEVADA
AREAS COVERED
GROUNDWATER

AD-A036 546 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/8
COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
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Adjectives are used to describe well yields quantitatively in the text and tables. They also correspond to well-yield ranges on subregion maps showing general availability of ground water. The following adjectives are used:

Adjective	Well Yield Gallons per Minute (gpm)
Inadequate (This range not used on the maps)	1
Small	1 - 20
Moderate	20 - 100
Moderately large	100 - 500
Large	500 - 2,000
Very large	2,000

Delineation of the areas on the maps is based on geologic information and greatly varying well data. Obviously, there are local areas that would fall into a different well-yield range if they were shown on a more detailed map.

Classification of areas on the basis of the yields of individual wells may be satisfactory from the viewpoint of the individual water developer and user, but the cumulative effects of continued withdrawal from a number of wells in an area may not be related to individual well yields, and generally can be determined only by detailed sophisticated studies. Cautionary statements are included where it seems probable that the combined effects of pumping several wells could result in withdrawal at rates exceeding the rate of replenishment.

Basis for Statements on Quality of Ground Water

In a large area such as the Columbia-North Pacific Region, ground-water quality varies considerably between aquifer units and from place to place within a unit. Frequently, water-quality data are scanty or entirely lacking. Statements and data regarding ground-water quality necessarily are broadly generalized throughout the report. However, an attempt was made to mention known occurrences of any element or constituent that may cause problems in the use of the water for domestic, public, industrial, or irrigation supply. The intention was not so much to give specific data on the degree of the hazard or problem, but to warn that a certain hazard may exist. More information on the degree of the hazard or problem can be obtained from the references cited. The bases for stating that certain elements or constituents of ground water are or may be excessive or hazardous are given in the following paragraphs.

Hardness of Water The classification given under "Quality" in the surface-water section was used in relating quantitative data on hardness to adjectives expressing degree of water hardness.

Arsenic, Fluoride, and Iron The Public Health Service lists recommended limits for certain constituents in water used for drinking. (168) Several chemical constituents are in excess of those limits in ground water at various places in the region. Statements that these constituents are, or may be excessive, mean that they exceed the limits set by the Public Health Service as abstracted below:

Constituent	Recommended Limit (mg/l)
Arsenic (As)	0.01
Fluoride (F)	1.3-1.7 1/
Iron (Fe)	.3

Boron, Percent Sodium, Sodium Adsorption Ratio The suitability of water for irrigation is dependent chiefly on the concentration of dissolved solids, boron, sodium, and bicarbonate. The U.S.D.A. Salinity Laboratory has published classifications expressing suitability of water with respect to concentration of dissolved solids, boron, SAR (sodium adsorption ratio), and residual sodium carbonate. The degree of the hazard is related not only to the concentrations of the constituents but also to the kinds of crops grown, the character of the soil, and agricultural practices. Thus, statements regarding hazards must be greatly generalized or be very specific. Statements in this report are generalized.

The general range in concentration of dissolved solids is given throughout the report. Usually not many data are available on boron. Statements that boron is or may be excessive mean that some water samples show boron in excess of 0.67 mg/l (however, boron in excess of 0.33 mg/l may be injurious to sensitive crops). Some data are available on SAR values and the general range in SAR is stated where possible. Many of the earlier chemical analyses report "percent sodium" rather than SAR. Where sodium is appreciably more than 50 percent of the total cations and dissolved solids are greater than 500 mg/l, sodium is considered as possibly excessive. As a rule, residual sodium carbonate has not been calculated for water analyses in the region and information on residual sodium carbonate is omitted from this report.

1/ See more complete discussion in section on surface water.

Silica The concentration of silica is included in many analyses of ground water in the region and, in nearly all, the content is between 10 and 70 mg/l. The more common range, however, is 20 to 50 mg/l. The usual range for silica in various aquifer units is given in the Regional Summary and at several places in the subregional chapters.

Areal Distribution of Ground Water

Ground water can be obtained at practically any place in the region. However, the quantities obtainable from a well range from a very few to many thousands of gallons per minute. Also, the depth to the water table to which a well must be drilled to obtain a ground-water supply ranges from a few feet to more than a thousand feet. These great differences are related chiefly to differences in the geology, the quantity of precipitation, and the topography and drainage.

About 42 percent of the region is underlain by aquifer units with low porosity and permeability that generally will yield only small supplies of ground water. It is fortunate that these units are confined mainly to thinly populated areas where water needs are comparatively small and surface-water supplies are plentiful. Generally, because of low permeability and low yields, the cone of depression surrounding an individual well is small and there is little mutual interference between wells. Thus, these aquifer units will supply water for tens of thousands of wells. A small percentage of the wells yield moderate quantities of water, sufficient for a small community, industrial, or commercial supply.

West of the Cascade Range the major aquifers are chiefly sand and gravel in the alluvial and glacial deposits. Many wells having moderate to large yields have been drilled in these deposits in the Puget Sound Subregion and in the Willamette, Cowlitz, Chehalis, and other river valleys.

In the plateaus of central and eastern Washington, north-central and northeastern Oregon, and west-central Idaho (parts of Subregions 1, 2, 3, 6, and 7) basalt of the Columbia River Group and similar basalt is the most widespread major aquifer and yields moderate to large quantities of water to many wells. Recharge from direct precipitation is generally small, but some areas receive additional recharge from streams draining adjacent mountain areas or from irrigation seepage. Over large areas of the plateau, however, recharge is entirely from the scanty local rainfall which limits the quantity of ground water than can be obtained.

Alluvial deposits are important aquifers along the Columbia River downstream from Grand Coulee Dam; in the Spokane, Okanogan,

Yakima, and Walla Walla River valleys; and in the Ephrata-Moses Lake and Pasco areas. The alluvial deposits also are major aquifers in valleys in northern Idaho and Montana in such places as the Rathdrum Prairie, and the Bitterroot, Flathead, Kootenai, and similar valleys.

Volcanic rocks, sedimentary strata, and valley alluvial deposits are important aquifers in south-central and southeastern Oregon and southwestern Idaho but have been developed only at a few places. The high altitude limits the crops that can be grown and the great depth to water at some places makes utilization of ground water expensive.

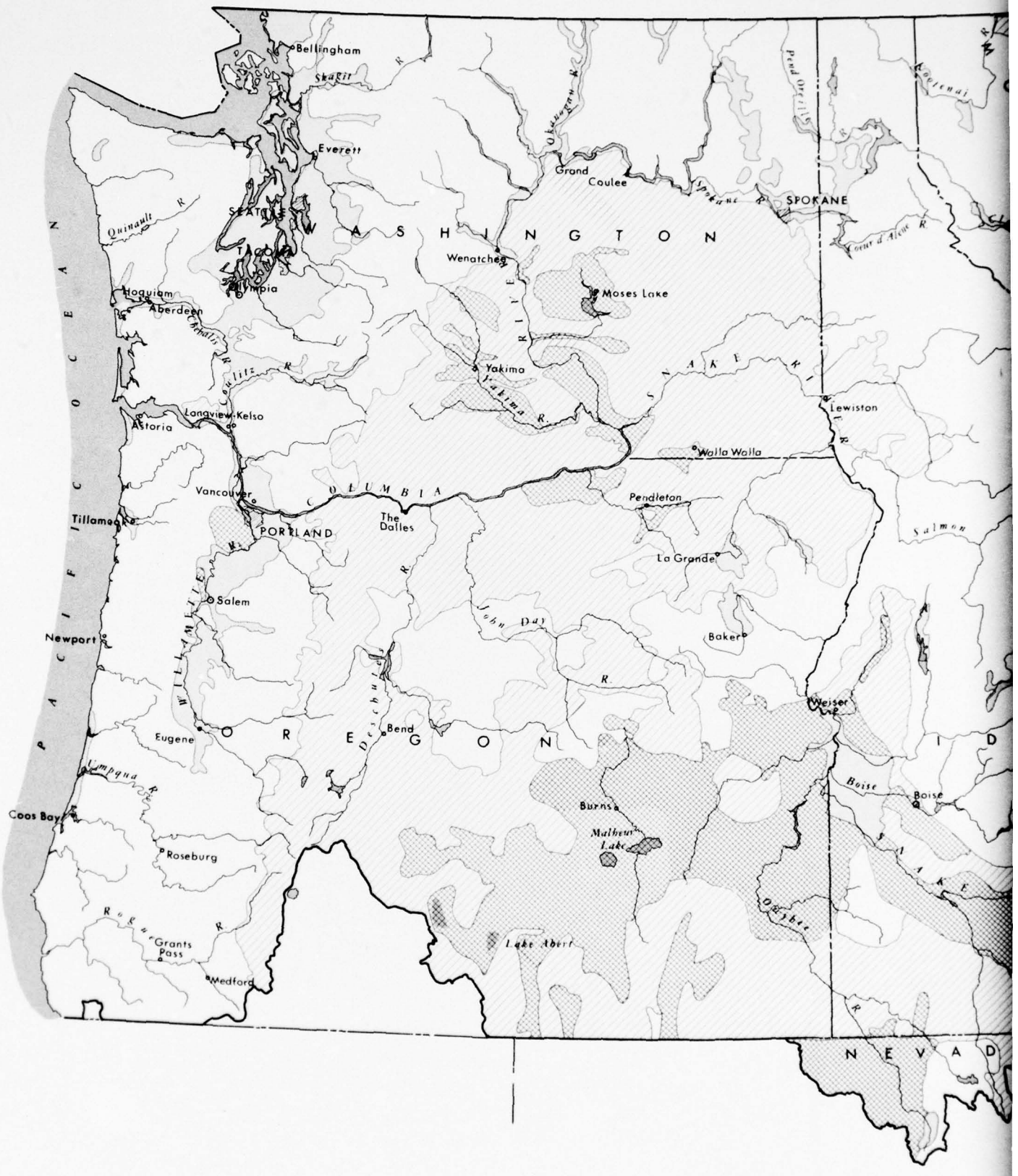
Extensive aquifers underlie the Snake River Plain and more ground water is withdrawn in that area than in any other part of the region. Basalt is the major aquifer in the eastern Snake River Plain (Subregion 4) but alluvial deposits are important near the Snake River and in tributary valleys. In western Idaho (Subregion 5), alluvium, basalt, silicic volcanic rocks, and sedimentary deposits are all important aquifers.

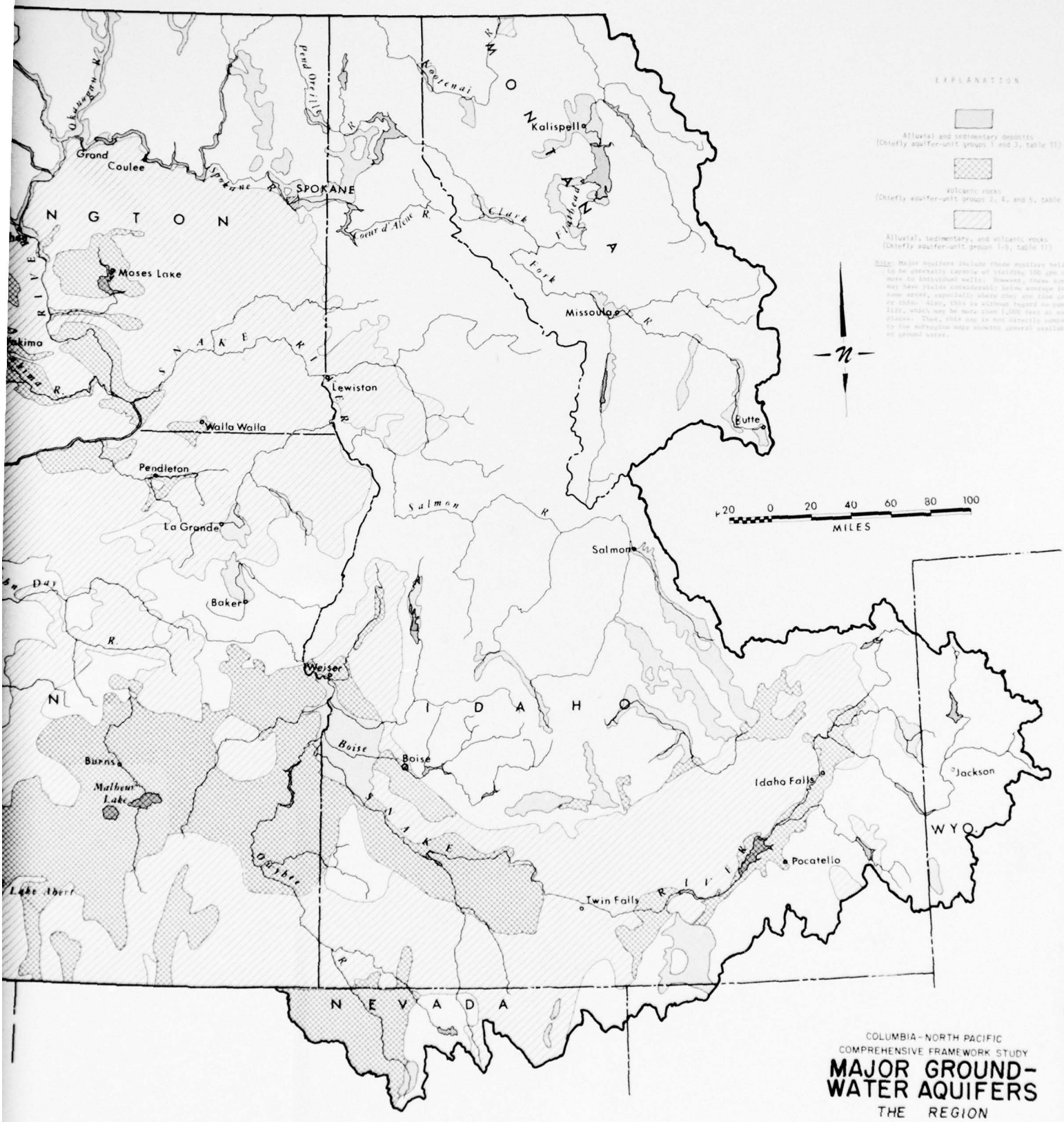
Major aquifers in the region are shown on the map, figure 20.

Aquifer Units and Their Hydrologic Characteristics

All available sources of information on ground water and geology were used in differentiating the aquifer units (references are given in the subregion descriptions). Published State geologic maps and other published and unpublished geologic maps, ground-water reports, and data were used in delineating the boundaries and determining hydrologic characteristics. Because of differences in mapping techniques, detail of coverage, dates of mapping, and for many other reasons, there are inconsistencies at the boundaries between maps. Generally, it was not possible to completely reconcile differences and a particular aquifer unit may include slightly different assemblages of strata from place to place. Several hundred geologic formations have been mapped in the region; to reduce these to a few aquifer units that could be shown on each subregion map required grouping of many formations into a single aquifer unit. Grouping was not always completely consistent from subregion to subregion.

All mapped geologic formations were grouped into 9 major aquifer-unit groups: 3 groups consist predominantly of sediments or sedimentary rocks; 4 are predominantly volcanic rocks; 1 is older Tertiary volcanic and sedimentary rocks, undifferentiated; and 1 includes all pre-Tertiary volcanic rocks. Because of the differences mentioned above, terminology and map symbols used for the units varied somewhat between subregions. Furthermore, many


Bellingham
Skagit R.
Everett
SEATTLE
TACOMA
Olympia
Quinault R.
Hoquiam
Aberdeen
Chehalis R.
Coulitz R.
Longview-Kelso
Astoria
Vancouver
PORTLAND
Tillamook
Newport
Willamette R.
Salem
Eugene
Umpqua R.
Coos Bay
Roseburg
Rogue R.
Grants Pass
Medford
PACIFIC OCEAN
Okanogan R.
Grand Coulee
Pend Oreille R.
Kootenai R.
Spokane R.
SPOKANE
WASHINGTON
Coeur d'Alene R.
Wenatchee
Moses Lake
Yakima R.
Yakima
SNAKE RIVER
Lewiston
Walla Walla
COLUMBIA R.
The Dalles
Pendleton
Salmon R.
La Grande
John Day R.
Baker
Deschutes R.
Bend
OREGON
Weiser
IDAHO
Boise R.
Boise
Burns
Malheur Lake
Owyhee R.
Lake Abert
NEVADA



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MAJOR GROUND-WATER AQUIFERS

THE REGION

FIGURE 20

Table 11 - Summary of Aquifer Units Columbia-North Pacific Region

No.	Aquifer Unit Group	Hydrologic Characteristics	Water Quality	Aquifer-Unit Symbol Used in Subregion											
				1	2	3	4	5	6	7	8	9	10	11	12
1	Alluvial and glacial deposits; mostly Pleistocene in age.	Includes very porous and permeable deposits at many places; small to very large yields.	Generally good to excellent; low dissolved solids.	Qg	Qg	Qal	Qal	Qal	Qal	Qal	QTal	QTal	Qal Qt	Qg	QTal
2	Younger volcanic rocks; Pliocene-Pleistocene in age.	Moderately porous and very permeable deposits at many places. Generally large to very large yields.	Generally good to excellent; low dissolved solids.	-	-	QTa	QTv	QTv	-	QTv	QTv	QTv	QTv	Qv	QTv
3	Younger sedimentary rocks; chiefly Pliocene in age.	Moderately porous; coarser-grained strata moderately permeable. Small to moderately large yields.	Good to fair; dissolved solids usually less than 700 mg/1.	Ts	-	Te	QTs	QTs	-	Ts	Ts	-	-	-	Ts
4	Silicic volcanic rocks; Miocene-Pliocene in age.	Low porosity; permeability highly variable; small to large yields.	Generally good to fair; *sodium, boron, fluoride* excessive at places.	-	-	-	Tsv	Tsv	-	-	-	-	-	-	-
5	Basaltic and andesitic volcanic rocks; middle Tertiary in age.	Low porosity; moderately high permeability in some interflow zones. Small to large yields.	Generally good; silica high; sodium, fluoride occasionally excessive.	Tcr Tv	Tcr	Tcr	-	Tb	Tcr Tv	Tmv	Tmv	Tsf Tcr Tlbv	- Tmv	-	Tb
2-5	Volcanic and sedimentary rocks, undifferentiated.	Characteristics of 2 to 5, above.	Characteristics of 2 to 5, above.	-	-	-	QTvs	QTvs	-	-	-	-	-	-	-
6	Older volcanic rocks; chiefly Eocene-Oligocene in age.	Low porosity; generally low permeability; usually small yields.	Good to fair; dissolved solids, percent sodium high in some deep wells.	-	Tv	Tov	Tcv	-	Tcv	-	Tov	Tov	Tv Tov	Tv	-
7	Older sedimentary rocks; chiefly Eocene-Oligocene in age.	Generally low porosity and permeability; small yields.	Shallow water good, deeper water may be moderately to highly saline.	-	TKc	Tc	Tos	-	-	-	Tos	Tm	Tm	Tos	-
8	Older volcanic and sedimentary rocks.	Low porosity, generally low permeability; small yields.	Generally good to fair; deeper water may be moderately mineralized.	-	-	-	-	Tvs	-	Tvs	-	-	-	-	Tvs
9	Pre-Tertiary rocks, undifferentiated.	Little porosity and permeability except in weathered zone. Small yields.	Generally good; low dissolved solids; some mineralized water.	pT	pT	pT	pT	pT	pT	pT	-	-	pT	pT	pT

formations as mapped contain both volcanic and sedimentary rocks. These formations are included with volcanic-rock or sedimentary-rock units according to the predominance of rock types. The aquifer-unit groups, their general hydrologic characteristics, and the differences in designations between subregions are summarized in table 11. The relation of geologic age and hydrologic characteristics of the aquifer-unit groups is shown in table 12.

Table 12 - Geologic Age of the Aquifer-Unit Groups and its Relation to Hydrologic Characteristics

AGE DIVISIONS		AQUIFER-UNIT GROUP								
		1	2	3	4	5	6	7	8	9
QUATERNARY	Holocene (Recent)									
	Pleistocene									
TERTIARY	Pliocene									
	Miocene									
	Oligocene									
	Eocene									
Pre-Tertiary: MESOZOIC PALEOZOIC Precambrian										
General well-yield and aquifer characteristics.		Moderate to very large well yields. Units include many excellent to outstanding aquifers.		Small to large yields. Includes many good to excellent aquifers.			Mostly small yields; moderate yields at favorable locations. Generally will support widespread development for domestic, other small supplies.			

Solid lines indicate usual age range; dashed lines indicate extended age range in some areas.

Alluvial and Glacial Deposits

Unconsolidated to slightly consolidated sedimentary deposits are included in this group. All Quaternary sedimentary deposits are included and, in several subregions, some late Pliocene deposits. The group includes fluvial, lacustrine, glacial, and windblown deposits. In most subregions the aquifer unit is shown as alluvial deposits of Quaternary age (Qal), but in Subregions 1, 2, and 11 where glacial and glaciofluvial deposits predominate, it was given the map symbol for glacial deposits (Qg). In Subregions 8, 9, and 12 some Pliocene basin-fill sediments were included with the alluvial deposits; this is indicated on the aquifer-unit maps by using the symbol "QTal."

The alluvial deposits have high porosities, generally ranging from 10 to 40 percent. Specific yields are somewhat less, ranging from practically zero for some clays to about 35 percent for well-sorted sands. The specific yield of most alluvial materials probably ranges between 5 and 30 percent. Permeabilities also differ over a very wide range. Some clays are almost completely impermeable, and silt generally has low permeability. Clean, well-sorted sand, and sand and gravel are moderately to highly permeable. Lacustrine deposits commonly are fine grained and have low to moderate permeability; stream channel and delta deposits are coarser and generally have moderately high to very high permeability.

Moderately to highly permeable aquifers occur extensively in the alluvial deposits of the Willamette Valley, Puget Sound basin, Spokane Valley-Rathdrum Prairie, Columbia Basin Project area, Snake River valley, and many smaller basins and narrower valleys throughout the region. Where a few tens to a hundred feet or more of permeable strata are saturated, individual wells commonly yield several hundred to several thousand gallons per minute. Alluvial and glacial deposits are important sources of ground-water supply in every subregion.

The quality of ground water in the alluvial deposits ranges from good to excellent. Dissolved solids generally are less than 300 mg/l and rarely exceed 500 mg/l except in some irrigated areas where the mineral content has increased because of percolation from irrigated lands. Dissolved solids exceed 500 mg/l in samples from some wells in those areas, but rarely exceed 1,000 mg/l. The water mostly is soft to moderately hard in areas where circulation of water is rapid and where the alluvial deposits are mostly noncalcareous. In more arid regions where circulation of ground water may be slower and the alluvial deposits contain considerable calcareous materials, the water is generally moderately hard to hard. Iron causes problems in many places, especially west of the Cascade Range.

Younger Volcanic Rocks

The younger volcanic rocks include lava flows and pyroclastic rocks ranging in age generally from upper Pliocene to Holocene (Recent). Older Pliocene volcanic rocks may be included at a few places. Most of the volcanic rocks are basaltic in composition, but they include some andesitic and locally some silicic volcanic rocks. The lava ranges from dense to vesicular, and some is open textured. Volcanic breccia, scoria, cinders, and ash are common.

The younger volcanic rocks are nearly everywhere moderately to highly porous. Vesicles are not filled and at many places the rock is open textured; that is, the rock appears to be a felted mass of crystals incompletely cemented together. Porosities determined for 108 samples from the Snake River Plain (86-158) ranged from 3.8 to 37.4 percent and averaged about 16 percent as determined from core and grab samples from flows. No data are available on porosities of lava from other parts of the region; however, the lava in other areas appears to be equally porous. Not all of the pores are interconnected, and specific yield is less than the total porosity. The average porosity and specific yield of the younger volcanic rocks as a whole are greatly increased by openings between successive flows and by interflow materials such as breccia, scoria, and cinders. Some of these interflow deposits probably have porosities and specific yields exceeding 50 percent.

Pumping tests of one to a few days' duration in the Snake River Plain suggest that the specific yield of the younger volcanic rocks ranges up to 20 percent and averages 4 or 5 percent. Because of slow drainage of the aquifer as it is dewatered and the relatively short duration of the tests, the average true specific yield may be higher. A value of 5 percent was used in computing storage for this report.

The younger volcanic rocks are among the most permeable in the world. However, the interior of an individual flow unit has low permeability; the coefficient of permeability of 24 core samples from the Snake River Plain averaged 0.14 gpd (gallons per day) per square foot. (86-158) In contrast, zones at and adjacent to the contacts of successive flows where the viscous lava of a later flow has failed to fill the irregular openings of the rough surface of a preceding flow are very permeable. At some places scoria, cinders, and other pyroclastic rocks between flows also are very permeable. The average coefficient of permeability of the Snake Plain aquifer may be on the order of 20,000 gpd per square foot. The average coefficient of permeability of the interflow zones, representing only a fraction of the total thickness of the aquifer, may be on the order of 100,000 to 200,000 gpd per square foot. The coefficient of transmissibility of the aquifer ranges generally from 1 to 60 million and the average may be greater than 5 million gpd per

foot. Data are not available regarding permeabilities and transmissibilities of the unit in other areas, but the large springs that discharge into streams draining the High Cascade Range in Oregon and Washington suggest equally high permeabilities for the younger volcanic rocks in those areas.

The younger volcanic rocks occur extensively in the plains and plateaus of Subregions 4 and 5, and in the High Cascade Range in parts of Subregions 7, 9, 10, and 12. The unit also occupies small areas at high altitudes in the Cascade Range in Subregions 3, 8, and 11.

The quality of ground water in the younger volcanic rocks generally is good to excellent. The concentration of dissolved solids generally ranges from less than 100 mg/l in parts of the Cascade Range where precipitation is great and circulation of ground water is comparatively rapid to about 500 mg/l in semiarid parts of the region. At some places where seepage from irrigated tracts is an important source of recharge, the concentration of dissolved solids may be greater, but rarely exceeds 700 mg/l. The water ranges from soft to very hard; generally where dissolved solids exceed 500 mg/l, the water is hard to very hard. However, at a few places, sodium is in excess of calcium and magnesium, the water is softer, and excessive sodium may be a problem. Rarely are boron or fluoride present in concentrations high enough to create problems. Silica usually ranges from about 20 to 60 mg/l and ground-water temperatures range from 45° to 60°F.

Younger Sedimentary Rocks

The younger sedimentary rocks include deposits ranging in age from middle Miocene to lower Pleistocene, but are chiefly of Pliocene age. They represent a somewhat older age range than the younger volcanic rocks. Included in this group are the Ellensburg, Latah, Payette, Salt Lake, Mascall, Madras, Dalles, and Rattlesnake Formations; the sedimentary rocks of the Idaho Group, the Wilkes Formation, and the lower part of the Troutdale Formation (the upper part is included with the alluvial deposits in Subregions 8 and 9). Unnamed deposits covering the same age range in southeastern Oregon are included. All of these units were deposited in a continental (nonmarine) environment. Marine-age equivalents are confined almost exclusively to Subregion 10, where they have not been separated from the much more extensive older sedimentary rocks.

The strata in the younger sedimentary rocks range from coarse conglomerates to fine-grained shales and tuffs. The materials are predominantly of volcanic origin; andesitic pebbles are common in the conglomerates, basalt, and other volcanic-rock grains are common in the sandy strata, and the finer-grained sediments are

predominantly tuffaceous. Because the deposits accumulated in separate basins of varying size, there are considerable lithologic differences from area to area. Deposits are commonly lenticular and the coarse-grained strata are cross bedded.

In general, according to the few data on porosity that have been collected, the deposits are moderately porous. Most of the deposits are slightly to moderately cemented so that porosity and specific yield usually are somewhat lower than in the alluvial deposits. Most aquifer tests have been performed on wells tapping aquifers where the water is confined, and the coefficient of storage is for artesian conditions and is not comparable to specific yield. The specific yield is believed to range commonly from a few percent for fine-grained materials to 20 percent for coarse-grained materials.

The deposits range from practically impermeable clay, shale, and tuff to very permeable sand and conglomerate. Not only do the individual strata within a formation differ greatly in permeability, but also some formations contain better aquifers than others. Stevens (152-14) notes that wells in the Idaho Formation yield up to 1,600 gpm (gallons per minute), Smith (145-46) lists wells in the Ellensburg Formation yielding up to 900 gpm, and Walker (in preparation) lists wells with yields up to 3,200 gpm in the Salt Lake Formation. However, the average yields are much less and yields of 100 to a few hundred gallons per minute are more common. Also, in some areas the deposits consist almost entirely of fine-grained materials where yields of more than a few tens of gallons per minute are difficult to obtain.

The younger sedimentary deposits are extensive in south-central Washington (Subregion 3), in eastern Oregon, southern Idaho, and northern Nevada (Subregions 4, 5, 7, and 12). The deposits are also delineated in basins in Montana (Subregion 1). Deposits in northern Idaho and northern and eastern Washington (Latah Formation) are not extensively exposed and, for the most part, are included with the basalt of the Columbia River Group with which they interfinger.

Water from the younger sedimentary deposits generally has a somewhat higher dissolved-solids content and a higher sodium percentage than water from the alluvial deposits and the younger volcanic rocks. Generally, the concentration of dissolved solids is less than 500 mg/l, but it may be more from some deep wells and exceeds 1,000 mg/l from some wells in Subregion 12. The water commonly is moderately hard to hard, but at places where the percent of sodium is high, the water may be softer. Boron and fluoride concentrations are excessive at a few places.

Silicic Volcanic Rocks

The silicic volcanic rocks include the widespread occurrences of silicic flows and pyroclastic rocks chiefly of Miocene and Pliocene age in southeastern Oregon, southern Idaho, and Nevada. The unit has been delineated only in Subregions 4 and 5. Similar rocks occur elsewhere in central and eastern Oregon but are of small extent or have not been separated from other formations on published geologic maps. Therefore, the silicic volcanic rocks in Subregions 7 and 12 have been included with the other volcanic-rock units.

The unit consists of silicic latite, rhyolite, and similar rocks. The silicic latite occurs chiefly as thick layers of devitrified welded tuff. Bedded tuff and latitic and rhyolitic flows are also common. Coarse pyroclastics, tuffaceous shale, sandstone, and conglomerate are interbedded with the volcanic rocks in some areas.

The hydrologic characteristics of the unit vary greatly. Thick sections of tuff, shale, and other fine-grained clastic and pyroclastic rocks have low permeability and yield little water. Fractured and rubbly flows, coarse pyroclastic rocks, and conglomerates are highly permeable and yield large quantities of water. No data are available on the porosity or specific yield. Judging by appearance, the unit probably is moderately porous; because much of the unit consists of welded tuff, fine-grained clastics and pyroclastics, and dense flows, the specific yield is believed to be much less than the porosity. A specific yield of 2 percent was used for estimating water in storage.

The silicic volcanic-rock unit is confined to two irregular belts flanking the Snake River Plain from Yellowstone National Park westward into Oregon. The rocks crop out in only a few small areas on the north flank of the plain, but outcrop areas are extensive along the south flank. A large part of the area is nearly uninhabited rangeland where few wells have been drilled. Wells have obtained large yields from the unit in the Bruneau-Grandview area in Idaho where it underlies the younger sedimentary- and volcanic-rock units. Water also is obtained from the unit in the Sailor Creek upland, the Salmon Falls Creek area, the Dry Creek-Goose Creek area, and on the bench south and east of Rexburg, all in Idaho. In parts of those areas the unit is overlain by younger volcanic and sedimentary rocks, and is tapped by wells that completely penetrate the overlying deposits.

Few data on water quality are available. In the Bruneau-Grandview area dissolved solids are less than 500 mg/l, the water is soft, and has a high percent of sodium. Fluoride concentrations

are excessive at places. In the Salmon Falls Creek area dissolved solids generally are less than 800 mg/l, but exceed that amount in a few samples. Sodium hazard is low, and fluoride concentrations generally are low.

Basaltic and Andesitic Volcanic Rocks

Basaltic and andesitic volcanic rocks of middle Tertiary age occupy more area than any other group except pre-Tertiary rocks. The formations included in the group are chiefly of Miocene age, but some middle and upper Oligocene and lower Pliocene rocks also are included. The Columbia River Group of Miocene to lower Pliocene age is the most widespread representative of the group, cropping out in southwestern Washington, northern Oregon, southeastern Washington, and northwestern Idaho. Other rocks included in the group are the Sardine Formation and the Little Butte Volcanic Series and similar rocks of the western Cascade Range in Oregon, and the Strawberry Volcanics, Picture Gorge Basalt, Steens Basalt, Picture Rock Basalt, Owyhee Basalt, and similar rocks in central and eastern Oregon and southwestern Idaho.

The lavas occur as very extensive sheets from a few tens to more than 100 feet thick. Both platy and columnar jointing are common. At many places pyroclastic rocks or sedimentary deposits are interbedded with the flows. Usually the central part of the individual flow is dense and the unbroken rock is nearly impermeable. Water can occur in and move through only the horizontal or vertical joints in that part of the flow; the permeability depends on the size and spacing of joints and generally ranges from very low to low. The upper parts of some flows are vesicular, scoriaceous, rough, and rubbly. If the succeeding lava flow incompletely filled openings in the preceding flow, interconnected openings were left that became water-bearing horizons. Coarse clastic and pyroclastic rocks between flows also are good water-bearing horizons, but silt, clay and other fine-grained sediments fill and seal the openings between flows and greatly reduce the permeability of interflow zones.

Because nearly all the permeability of the volcanic rocks is in the interflow zones, a single flow generally yields little water. Where thick sections of basalt occur, containing several to many interflow zones, moderate to large yields of water can be obtained. The yield of a well thus is roughly related to the thickness of the aquifer unit penetrated. For basalt of the Columbia River Group, a well penetrating several interflow zones will yield roughly 1 to 1-1/2 gpm per foot of penetration below the top of the saturated zone. At many places the central part of the flow has such low permeability that it is effective in confining water in the interflow zone beneath. Moderate to large differences in head have been noted in drilling through successive interflow zones.

Little information is available on the porosity and specific yield of the basaltic and andesitic volcanic rocks. Mostly the porosity and specific yield of the central part of flows are very small. In contrast, the porosities and specific yields of some interflow zones may range up to 40 percent. However, because the interflow zones are generally separated by many feet of rock of low porosity, the average porosity and specific yield are low. A value of 1 percent was used for specific yield for calculating ground water in storage in this unit. Coefficients of storage determined from pumping tests commonly are much less because the aquifers generally react as artesian aquifers during the test and thus do not give the true specific yield.

The basaltic and andesitic volcanic rocks are important aquifers over a wide area. Basalt of the Columbia River Group is the chief aquifer in Subregions 2 and 3 and is important in parts of Subregions 1, 5, 6, and 7. Many hundreds of wells yield moderately large to large quantities of water for irrigation, municipal, and industrial use, and many smaller wells are used for domestic supply. Other units of the group furnish comparable supplies in parts of Subregions 5, 7, and 12. Basalt of the Columbia River Group also yields moderate to moderately large supplies at some places in the northern part of Subregion 9. The Sardine Formation, the Little Butte Volcanic Series, and similar rocks yield moderate quantities at some places along the western flank of the Cascade Range in Subregions 9 and 10.

The chemical quality of the water is good for most uses. Concentration of dissolved solids commonly is less than 400 mg/l, and the water is moderately hard to hard. Silica generally ranges from 40 to 60 mg/l. The sodium adsorption ratio usually is less than 2 but at a few places is 5 to 10. Fluoride and sodium concentrations are high in some deep wells, apparently where water has been in the aquifer for a long time.

Volcanic and Sedimentary Rocks, Undifferentiated

The geology of extensive areas in southeastern Oregon and northern Nevada has been mapped only in a very general way. These areas are known to be largely underlain by volcanic and sedimentary rocks of Miocene or younger age which are comparable to the aquifers included in groups 2, 3, 4, and 5 of table 11 and described in previous paragraphs. The rocks are shown on aquifer-unit maps of Subregions 4 and 5 under the symbol "QTvs." Most of the area is semiarid, largely uninhabited, rangeland, and a few data are available on ground water. Undoubtedly, moderately large to large yields can be obtained at some places; however, over much of the area, the depth to water is several hundred to many hundred feet, and probably exceeds 1,000 feet at some places.

Older Volcanic Rocks

The older volcanic rocks, group 6 in table 11, are chiefly of Eocene and Oligocene age, but may include some volcanic rocks of Miocene age where these have not been separated from the older volcanic rocks. They also include some small mapped areas of Miocene rocks that were too small to show separately. In order to keep the aquifer-unit map as simple as possible, igneous rocks intruded into the volcanic rocks are also included.

The older volcanic rocks consist chiefly of andesite and basalt flows, flow breccia, pyroclastic rocks, and some interbedded sedimentary strata. In the Coast Ranges, marine sedimentary strata are interbedded with volcanic rocks. The older volcanic rocks have been greatly altered and the original pore space has been largely filled with alteration products and secondary mineralization. Vesicles and other pores have been filled with zeolites, calcite, and similar minerals; and the coarse-grained fragments in the clastic and pyroclastic rocks have been largely altered to clayey minerals. Thus, these rocks generally have both low porosity and low permeability.

Drilled wells generally obtain small yields from joints and fractured zones; usually the quantities are sufficient for domestic use. About 5 to 10 percent of the wells yield less than 1 gpm and about an equal percentage yields more than 20 gpm. The weathered soil and subsoil zone apparently is somewhat more porous than the underlying rock, and dug wells generally yield supplies sufficient for domestic use. The water table fluctuates considerably, however, and many dug wells go dry during periods of drought.

Older volcanic rocks (Tov) are shown on the aquifer-unit maps of Subregions 8, 9, and 10; that is, west of the Cascade crest, and in part of Subregion 3 within the Cascade Range. Aquifer units shown with the map symbol "Tv" in Subregions 2 and 11 also are classed with this group although they cover a slightly wider age range and include some Miocene volcanic rocks. In Subregions 4 and 6 the Challis Volcanics (Tcv) represent the group, but small areas of Challis Volcanics in Subregion 5 are included with the older volcanic and sedimentary rocks described later.

The quality of the shallow water generally is good to fair, dissolved solids are less than 500 mg/l, and the water is moderately hard to hard. The deeper water usually has higher concentrations of dissolved solids and some wells in the Coast Range yield saline water which apparently has migrated from interbedded or underlying marine sedimentary strata.

Older Sedimentary Rocks

The older sedimentary rocks include strata chiefly of Eocene and Oligocene age. Small areas of Miocene strata are included at a few places to keep the map as simple as possible. Some areas of Tertiary intrusive rock also are included. In areas where the older sedimentary strata are mostly of marine origin, as in Subregions 9 and 10, they have been shown with the symbol "Tm." Where they are dominantly of nonmarine origin or contain large areas of nonmarine rocks, as in Subregions 4, 7, and 11, they are shown with the symbol "Tos." In Subregion 3, the symbol "Tc" is used after Sceva. (58) In Subregion 2, the older sedimentary rocks consist of Cretaceous to Paleocene nonmarine strata shown on the State geologic map as "TKc" and that symbol is used on the aquifer-unit map for Subregion 2.

The marine sedimentary rocks are chiefly sandstone, shale, and mudstone, with some limestone and conglomerate. Most of the shale and mudstone is tuffaceous. Lava flows and pyroclastic rocks are interbedded with the sedimentary strata at some places. The nonmarine sedimentary rocks are mainly tuffaceous shale, siltstone, and sandstone with some conglomerate, coal beds, and pyroclastic rocks. For the most part, the older sedimentary rocks have been compacted and cemented so that the original porosity and permeability have been greatly reduced. In the unweathered rock most of the water is contained in and moves through joints and other fractures. At some places quartzose sandstone has been less altered and cemented and retains more of its original porosity and permeability.

Wells that tap the marine sedimentary strata may have moderate yields but most yield less than 10 gpm. Roughly 90 percent of the wells yield 1 to 20 gpm with perhaps 5 percent below and 5 percent above that range.

No quantitative data are available on the porosity and specific yield. The specific yield probably is much less than the porosity and may be less than 1 percent for the unweathered rock. The specific yield of the weathered zone is believed to be somewhat greater.

Many hundreds of wells obtain domestic water supplies from these rocks in Subregions 8, 9, 10, and 11. A few wells have moderate yields sufficient for municipal and small industrial supplies. In Subregions 2, 3, and 4, the aquifers generally underlie uninhabited areas and are not utilized extensively.

The shallower water generally is of good to excellent quality with dissolved-solids concentrations of less than 500 mg/l. The deeper water is brakish and some water from marine strata is highly saline. Also, boron and fluoride concentrations commonly are

excessive, the sodium adsorption ratio may be 5 to 10 and, at a few places, higher.

Older Volcanic and Sedimentary Rocks

The older volcanic and sedimentary rocks include several formations in eastern Oregon and Idaho that consist of both volcanic and sedimentary strata. In Subregions 5 and 7, the unit consists chiefly of the Clarno Formation of Eocene age and the John Day Formation of upper Oligocene and lower Miocene age. The Clarno Formation consists of basaltic to rhyolitic flows, breccia, tuff, and volcanic conglomerate. The John Day Formation consists chiefly of tuffaceous siltstone, rhyolitic eolian tuff, and welded tuff. The Challis Volcanics cropping out over a few square miles in the extreme eastern part of Subregion 5 are also included. In Subregion 12, tuffaceous sedimentary rocks, tuff, welded tuff, and silicic flows of Miocene age are also included. These latter rocks occur mainly in the southern part of Subregion 12 and may be in part correlative with the silicic volcanic rocks (Tsv) of Subregions 4 and 5.

Generally these aquifer units have low porosities and permeabilities and yield only small quantities of water. An occasional well in the Clarno and John Day Formations yields 50 to 100 gpm, rarely more. The scanty data available suggest that the younger rocks in the southern part of Subregion 12 may be capable of yielding larger supplies at some places.

Water quality usually ranges from good to fair. Water at shallower depths and in humid areas where circulation is more rapid has dissolved-solids concentrations of 300 to 500 mg/l. In semiarid areas where the depth to water may be great and circulation slow, the concentrations of dissolved solids may exceed 1,000 mg/l. Sodium and boron concentrations are excessive in water from some wells.

Pre-Tertiary Rocks

All rocks older than the Tertiary period have been placed in a single group. In a few locations intrusive rocks of Tertiary age also are included. Because the age range is much longer from Precambrian to Tertiary than for all other groups combined, and because lithologic types are not differentiated, rocks of this group are very diverse. However, with few exceptions, they have the common characteristics of low porosity and low permeability. Fortunately, from the standpoint of ground-water supply, these rocks crop out chiefly in uninhabited mountainous areas where there is little need for wells of large or even moderate yield.

The pre-Tertiary rocks in the northern part of the region, in Subregions 1 and 2, include low-grade metamorphic rocks of the Precambrian Belt Series, sedimentary strata of Paleozoic and Mesozoic age, and granitic to dioritic intrusive rocks of Mesozoic and Tertiary age. In the northern Cascade Range, in Subregions 3 and 11, the group consists chiefly of metamorphic and intrusive rocks. The pre-Tertiary rocks in central Idaho, in Subregion 6, and in parts of Subregions 4 and 5, are chiefly granitic intrusive rocks of the Idaho Batholith with some metamorphic rocks around the margin of the batholith. The pre-Tertiary rocks in eastern Idaho and Wyoming in Subregion 4, include limestone, sandstone, shale, and other sedimentary strata of Paleozoic and Mesozoic age. The pre-Tertiary rocks of the Blue and Wallowa Mountains in Subregions 5, 6, and 7, and the Siskiyou and Klamath Mountains in Subregion 10, are mainly of Mesozoic age and include sedimentary and volcanic rocks, in part metamorphosed, and igneous intrusive rocks. In the Olympic Mountains the pre-Tertiary unit consists mostly of marine sedimentary rocks and interbedded volcanic rocks of Mesozoic and early Tertiary age.

With few exceptions the unweathered pre-Tertiary rocks have very low porosity. The porosities of most intrusive igneous rocks and gneiss, schist, and similar metamorphic rocks probably are less than 1 percent. Sedimentary strata--shale, sandstone, limestone, and similar rocks--have somewhat larger porosities, but the average porosity of the pre-Tertiary rocks probably is not more than a few percent. Specific yields probably are much less. Porosities and specific yields of the weathered rock probably are considerably higher.

The permeability of most of the rocks in the pre-Tertiary aquifer unit generally ranges from very low to low and most wells yield only small quantities of water. However, a few wells obtain moderately large to large yields from Paleozoic limestone in the Goose Creek and Raft River basins.

Water from shallow aquifers, obtained from springs, dug wells, and shallow drilled wells, generally has low concentrations of dissolved solids and no harmful constituents in excessive concentration. Some deeper wells yield more highly mineralized water, and many mineralized hot springs rise along faults or fractures in these rocks, especially in and near the Idaho Batholith.

Potential Aquifers

There probably are few unknown aquifers in the region but the knowledge about every aquifer is incomplete, and for some aquifers is very sketchy, particularly in the more arid parts of Idaho, Oregon, and Nevada that are sparsely inhabited and largely

unexplored with respect to ground water. The geologic mapping in much of those areas has been of a reconnaissance type; the general nature and character of the aquifers are known but their actual potential can only be inferred. Undoubtedly, wells with large yields can be drilled at many places in those areas; the same aquifers supply large yields in other areas. The low recharge and great depth to water, however, presumably would prevent widespread intensive development of ground water in the unexplored arid parts of the region.

There is another type of "potential" aquifer. That is the geologic formation or body of rock that has all the requisite characteristics for being a good aquifer except that it is above the water table and is not saturated. Such potential aquifers become actual aquifers when the water table rises sufficiently owing either to increased recharge as a byproduct of irrigation from a surface-water supply, or from a program of artificial recharge. Potential aquifers of this type occur in the more arid parts of the region, particularly in Subregions 5 and 12. These aquifers are discussed in more detail in the subregional sections of the report under the headings "Present Use and Future Availability," and "Artificial Recharge."

Water in Storage

Water occurs beneath the earth's surface to depths of several thousand feet, and the quantity of water stored is many times the quantity stored in lakes, streams, and reservoirs on the surface of the continents. However, most of this water is in dead storage; it cannot be counted as a part of the water resource as only the upper part of the ground-water reservoir can be utilized. Disregarding considerations of water quality, the depth limit to which the water level can be lowered in an area is almost entirely an economic limit. In areas where permeable alluvium overlies rocks of low permeability, the limit may be near the base of the alluvium because it would be uneconomic to develop additional supplies by lowering the water table into the underlying rock. In areas where the water table is in rocks of moderate or low permeability, it probably would be uneconomical to construct and pump the large number of wells that would cause a large and extensive lowering of the water table. On the other hand, in areas where permeable deposits extend to depths of 500, 1,000, or more feet, it may be economically feasible to lower the water table 100 feet or more. Another factor to consider is that in many areas the depth to which stored ground water can be economically exploited has tripled or quadrupled in the past 25 years and may increase severalfold in the future.

The above factors were considered in assigning a depth interval for computing the quantity of ground water in storage in the various subregions.

For the alluvial and glacial deposits a saturated thickness of 50 feet was assumed in all subregions except Subregion 12. In many valleys the average saturated thickness of the deposits may be little more than 50 feet. In basins where the saturated thickness may be greater, there appears to be little likelihood that a general lowering of the water level of more than 50 feet will occur in the foreseeable future.

For all aquifer units of low permeability included in groups 6 through 9, table 11, a depth interval of 50 feet below the top of the saturated zone was used for computing the quantity of water in storage.

The middle to late Tertiary volcanic and sedimentary rocks included in aquifer-unit groups 2 through 5, table 11, are moderately to highly permeable in many places. In the more humid parts of the region, including Subregion 1, and all subregions west of the Cascade Range, it seems highly unlikely that there will be widespread lowering of the water table; therefore, a depth interval of 50 feet was used for those subregions. In the arid to semiarid areas east of the Cascade Range where those rocks are important aquifers, extensive lowering of the water table may become economically feasible. A depth interval of 100 feet was used for those aquifer units in that area.

It should not be inferred from the above discussion that a general lowering of 50 or 100 feet will occur, but only that these are probable limits for the next 40 or 50 years. Furthermore, local lowering of the water table in excess of these limits may well occur.

In this report the volume of water in storage is defined as the volume that would be obtained by gravity drainage and is the product of area, assigned thickness, and specific yield.

So far as is known, no determinations of specific yield have been made for alluvial aquifers in the Columbia-North Pacific Region. A report by Johnson (56) summarizes the information available on specific yields. Most of the data are for tests made in California and a few other western states. A specific yield of 20 percent was selected for the alluvial and glacial deposits in this region on the basis of the data contained in that report.

Determinations of specific yield for the younger volcanic rocks (QTv, QTa, Qv), have been made by laboratory and field tests in Subregion 4 and are summarized in the description for that subregion. On the basis of these data a specific yield of 5 percent was used for the younger volcanic rocks in all subregions.

The third aquifer-unit group, the younger sedimentary rocks (QTs, Ts, Te), are slightly to moderately consolidated and cemented so that their porosity is somewhat less than that of the alluvial deposits. In general they are finer grained than the alluvium. No data are available on specific yields of these materials. A specific yield of 10 percent was assumed for these deposits for Subregions 3, 4, and 5. In Subregions 1, 7, 8, and 12, where the deposits are believed to be generally finer grained, a specific yield of 5 percent was used.

The specific yield of flows in the silicic volcanic rocks probably is less than 1 percent; however, the unit includes much pyroclastic material and sedimentary interbeds. A specific yield of 2 percent was assumed for computing the water in storage.

No quantitative data are available regarding specific yields of aquifer-unit groups 5 through 9 (table 11). However, at several places moderate withdrawals have caused large local declines in the water table--a qualitative indication of low specific yields. The unweathered rocks probably have specific yields not exceeding 1 percent. The weathered rock has a much higher porosity and specific yield; residual soils may have specific yields of 10 to 15 percent. So far as is known, no quantitative data are available for the weathered zone in the Columbia-North Pacific Region. However, tests in Georgia (153) indicated that the specific yield of the saprolite (highly weathered rock) derived from the weathering of schist and gneiss, exceeded 20 percent to depths of 40 feet. The specific yield decreased very sharply below 40 feet and approached zero in the unweathered rock. These data may not be representative of rocks in the Columbia-North Pacific Region, but do lend credence to the general assumption that the weathered material has a much higher specific yield than the underlying unweathered rock.

In the arid and semiarid areas the weathered zone generally is thin; furthermore, because of low recharge, the water table at many places is in the unweathered rock below the base of the weathered zone. Therefore, for those areas, a specific yield of 1 percent was used in computing water stored in aquifer-unit groups 5 through 9. In humid areas, the depth of weathering is greater and the water table is nearer the surface because of much greater recharge. A specific yield of 2 percent was used in those areas.

The area occupied by each aquifer-unit group and the estimated quantity of water in storage within the specified depth interval is given in table 13.

Table 13 - Summary of Storage, Recharge, and Discharge of Ground Water in Aquifer-unit Groups in the Region

Aquifer-unit Group	Area: Square Miles (thousands)	Area: Acres (millions)	Quantity of Water in Storage 1/ (millions of ac-ft)	Gross Annual Natural Recharge and Natural and Pumped Discharge (millions of ac-ft)
1. Alluvial and Glacial Deposits	41.3	26.5	270	36
2. Younger Volcanic Rocks	28.9	18.5	80	28
3. Younger Sedimentary Rocks	16.1	10.3	80	2
4. Silicic Volcanic Rocks	7.7	4.9	10	1
5. Volcanic Rocks of Middle Tertiary Age	58.0	37.2	38	10
2-5. Volcanic and Sedimentary Rocks, Undifferentiated	5.5	3.5	18	.5
6. Older Volcanic Rocks	13.5	8.6	8	7
7. Older Sedimentary Rocks	11.4	7.3	4	6
8. Older Volcanic and Sedimentary Rocks	6.5	4.2	3	1
9. Pre-Tertiary Rocks, Undifferentiated	82.3	52.6	47	29
TOTAL (rounded)	271	174	550	120

1/ Within a specified depth interval as explained in the text.

Recharge and Discharge

The source of recharge is precipitation but the recharge reaches aquifers in a variety of ways which are dependent upon such factors as the amount and rate of precipitation; the character of the aquifer and overlying material including the soil; the pattern and spacing of surface drainage; and the ruggedness of the terrain. Chief immediate sources of recharge or ways in which recharge occurs include the following:

1. Direct infiltration of precipitation.
2. Snowmelt (delayed infiltration).
3. Seepage from streams.
4. Seepage from irrigation (canals, laterals, fields).
5. Lateral or vertical inflow from adjacent aquifers.

Recharge from direct precipitation predominates in the humid parts of the region--in the entire area west of the Cascade Range, and in the intermountain basins east of the Cascade Range. In these relatively low-lying areas, recharge from direct precipitation occurs throughout the rainy season, during the fall, winter, and spring. At higher altitudes, recharge from direct precipitation occurs in the fall and spring but most winter precipitation occurs as snow, and recharge from snowmelt is largely in the spring.

Recharge by seepage from streams occurs in every subregion, but is more important in areas where precipitation is low, as in parts of Subregions 3, 4, 5, 6, 7, and 12. In general, such recharge occurs where streams draining mountainous areas with moderate or high precipitation enter semiarid or arid basins underlain by porous and permeable deposits. Because discharge of many of these streams is greatest during the spring snowmelt period, recharge to aquifers

occurs chiefly during that period. In their lower courses, the same streams, or the major trunk stream of the basin, receive inflow from ground water. (Figure 24c)

Recharge from irrigation seepage occurs in all areas where irrigation is extensive but is most significant in the more arid parts of the region. Recharge from irrigation seepage is the major source of recharge to alluvial and volcanic-rock aquifers in parts of Subregions 2, 3, 4, and 5. Recharge is so great that water logging has become a problem at many places. Discharge from aquifers underlying irrigated areas is into drains and streams in the low-lying parts of the basins.

Many aquifers have restricted areas of outcrop and are recharged chiefly by leakage from overlying aquifers through imperfectly confining beds. Discharge of some aquifers occurs in the same way; whether the water is moving up or down at a particular place depends upon the relative head in the shallow and deep aquifers. Generally, the hills around the margins of a basin are recharge areas, the water level in the shallowest aquifer is the highest, and water leaks downward to recharge deeper aquifers. In some valleys, water in the deeper aquifers is under pressure and leaks upward into the shallow aquifer which may also be recharged from above by precipitation and seepage from streams and irrigated areas. Discharge from the shallow aquifer is into drains and streams.

The relations between recharge from various sources and changes in water levels are shown in figure 21. If data on specific yield are available together with enough water-level data to show the average changes and rates of change of water level in an aquifer, a quantitative appraisal of recharge can be made. That method was used at a few places for estimating recharge for this report. Generally, however, data are sufficient for making only rough estimates.

Ground-water discharge can be measured directly as spring outflow or indirectly as a gain in discharge of a stream reach. Ground water is a component of discharge of all streams; several streams in the region are almost entirely ground-water effluent. The ground-water component of discharge can be separated from the direct flow component on a stream-discharge hydrograph. Generally, where ground water is the major component, as for Birch Creek in Idaho, or the Metolius River in Oregon, this is not difficult. Where the ground-water component is less than 50 percent of the total, separation is considerably more difficult.

Several hydrologists (55-48 to 53, and 143-24 to 26) have used flow-duration curves for determining the ground-water component of streamflow. In this study the lower right-hand portion of the

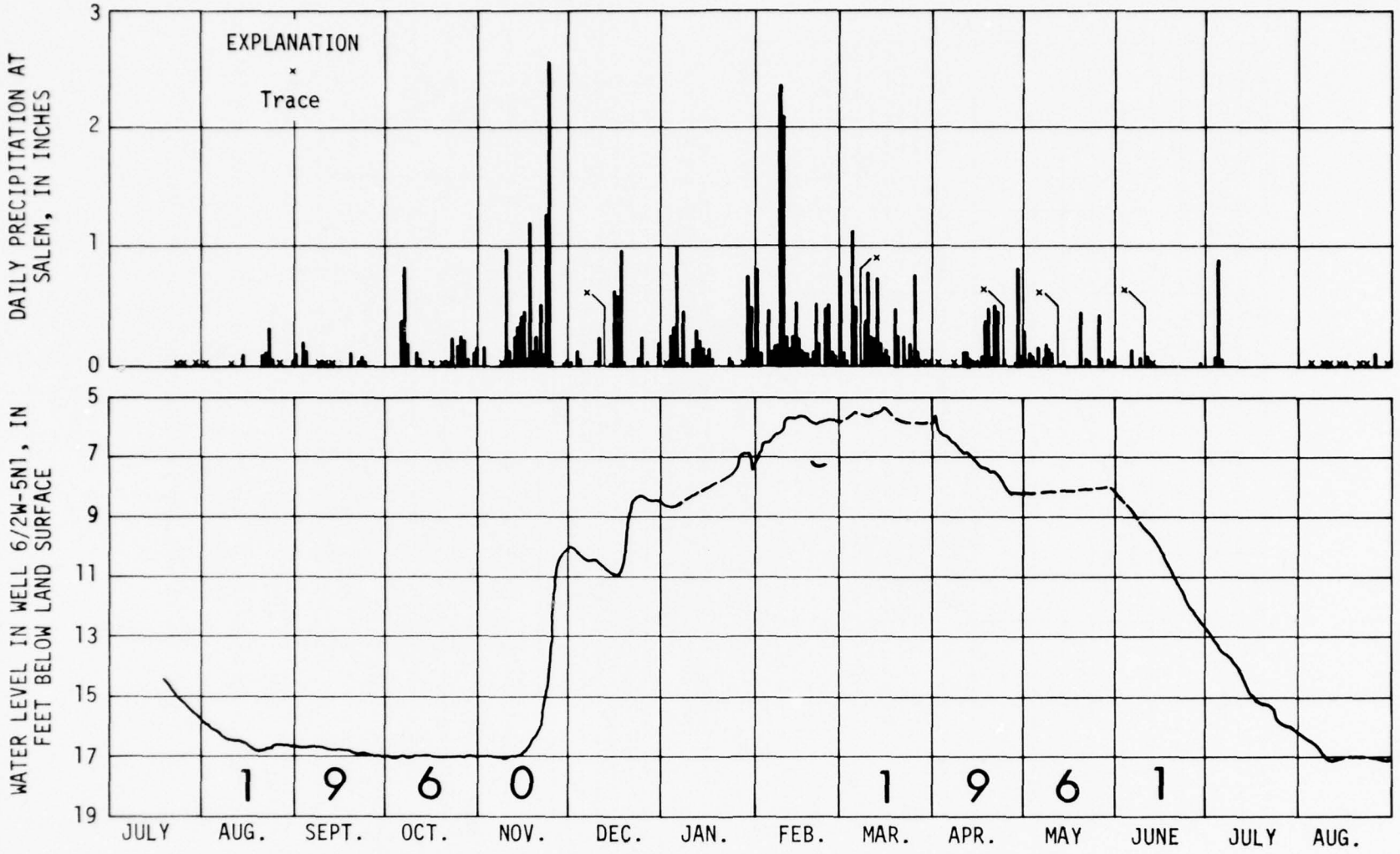
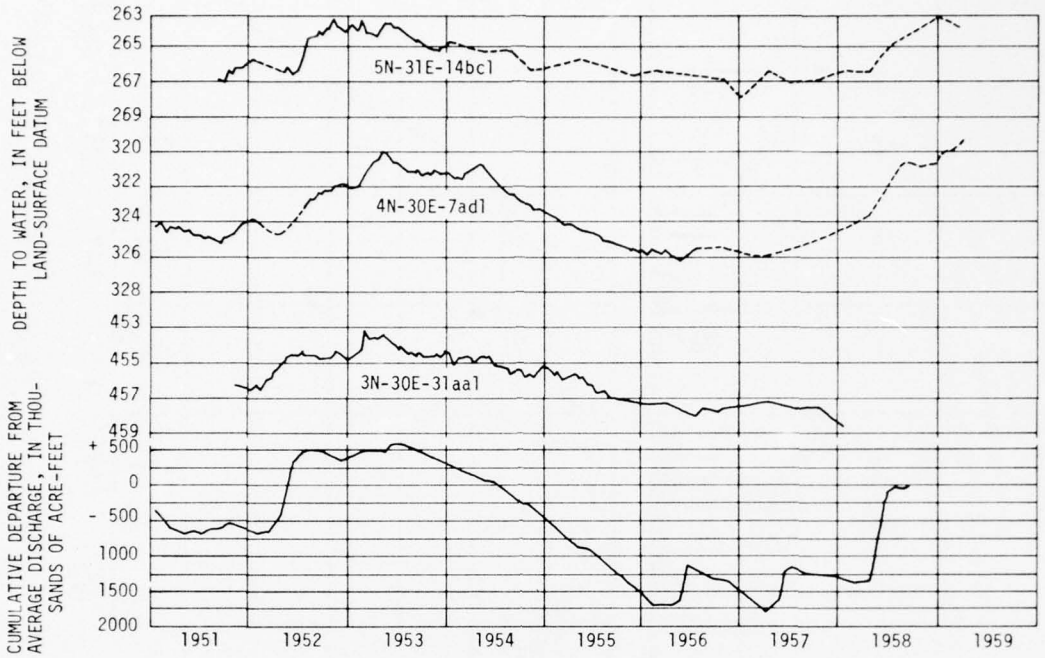
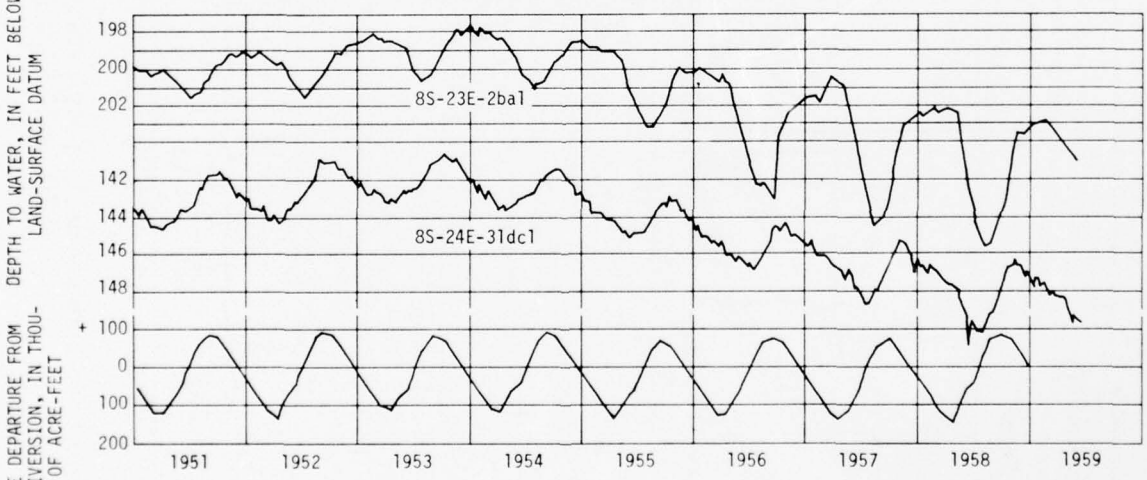


FIGURE 21A.- Relationship between daily precipitation recorded at Salem, Oreg., and changes in water level in well 6/2W-5N1, after Don Price (123-48).



B - Hydrographs of three wells at the National Reactor Testing Station and the cumulative departure from the average combined discharge of the Big and Little Lost Rivers, after Mundorff and others (86-166).



C - Water levels in two wells and cumulative departure from average diversions to Minidoka North Side Canal, after Mundorff and others (86-170).

FIGURE 21. Hydrographs of Water Levels in Selected Wells.

flow-duration curve, usually that portion of the curve that is exceeded 60 to 90 percent of the time by a particular discharge, was assumed to be ground-water discharge. This curve was extended upward with a smooth convex curve to the probable maximum rate of ground-water discharge, a point determined by study of streamflow hydrographs. Hydrographs and flow-duration curves are available for a number of streams that are supported entirely or almost entirely by ground-water discharge. Flow-duration curves of these streams were used in checking the shapes of the ground-water component of streamflow for other streams in the region.

The ground-water component of streamflow was determined in this way for more than 40 streams representing different geologic and hydrologic terranes and climatic conditions. These data were used in estimating the annual discharge in inches over the area for the various aquifer units in the different subregions. Examples of stream hydrographs and flow-duration curves used are shown in figures 22 and 23.

This method of estimating ground-water discharge is inexact because the quantitative relation of ground water and surface water in most cases is not known. However, the method is useful in comparing the ground-water yields of different terranes and as a first approximation of the annual discharge from the various aquifer units.

It should be noted that the ground-water discharge determined by the above method includes only that part of the ground-water effluent that becomes streamflow and is measured at a particular gaging station. In some river basins, large quantities of ground-water effluent are intercepted and consumed by vegetation as the ground water moves into areas near the drainage channels where the water table is near the surface. In some basins the ground-water effluent discharged by evapotranspiration at times may be greater than the quantity appearing in the streams. No attempt was made in this report to evaluate quantitatively evapotranspiration from ground water, except in Subregion 12.

The gross annual natural recharge and gross annual natural and pumped discharge from the different aquifer-unit groups in the region are given in table 13. The gross recharge and discharge are assumed to be equal because the annual change in ground-water storage, both on a regional basis and for any subregion, is so small a part of the total recharge as to be far less than the error in estimation. The values are for gross recharge because some of the water has moved through the ground-water phase of the hydrologic cycle two or three times in its travel from headwaters areas of river basins, before finally leaving the region. The total gross annual recharge and discharge is estimated to be about 120 million acre-feet a year; net annual recharge and discharge probably are on the order of 100 million acre-feet a year.

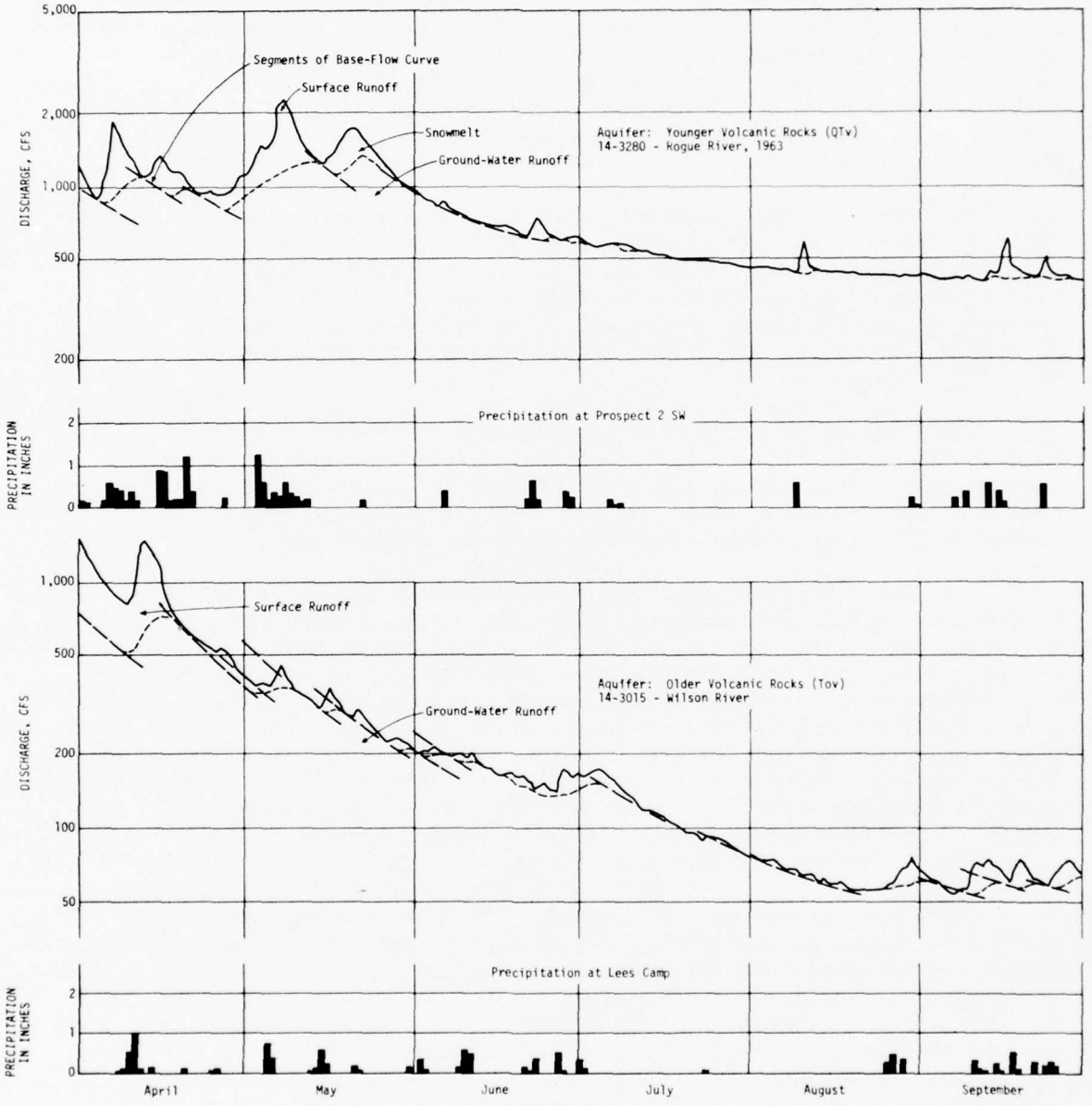


FIGURE 22. Hydrographs Showing Low-Flow Characteristics of Selected Streams

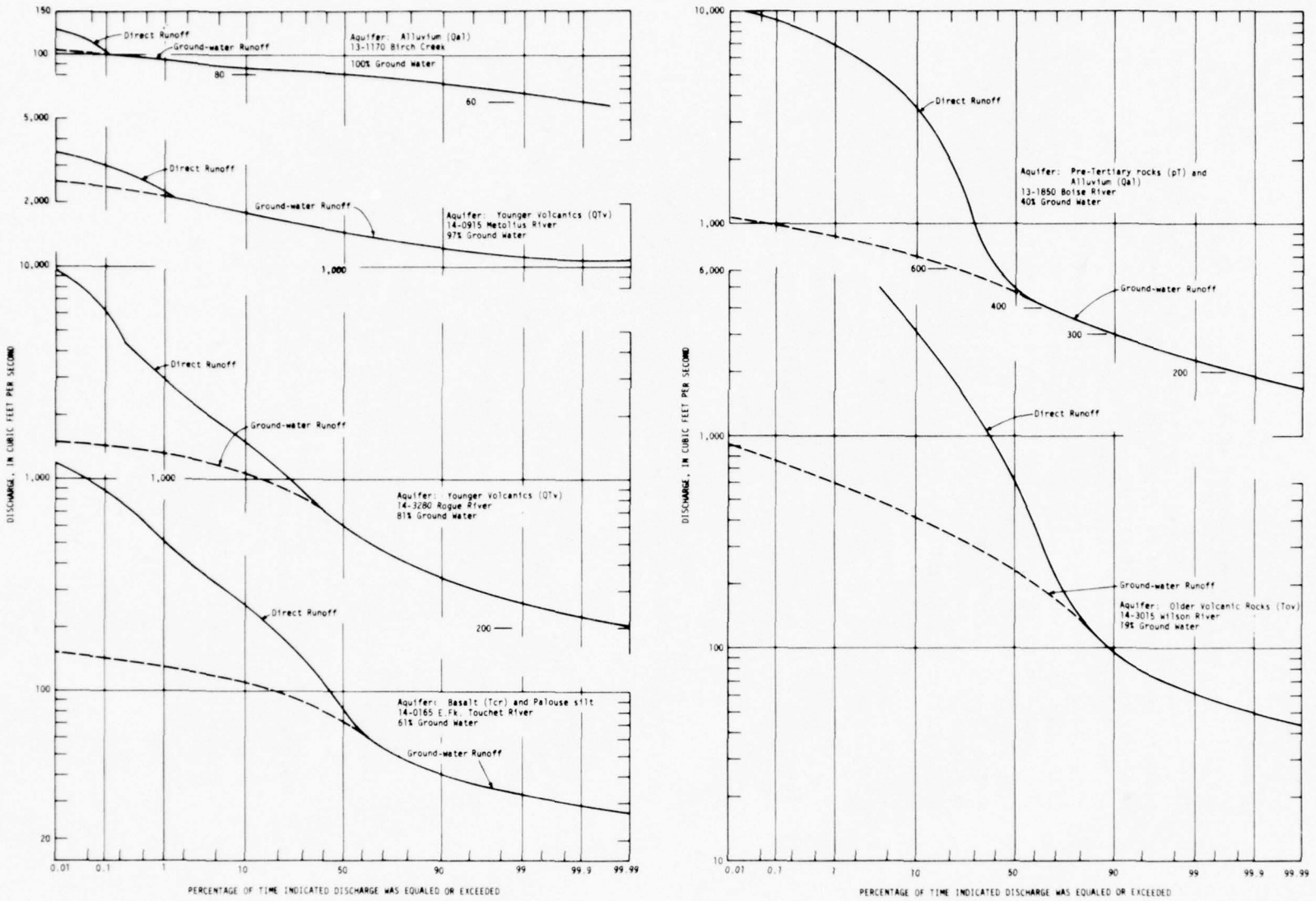


FIGURE 23. Flow-Duration Curves Showing Separation of Direct Runoff and Ground-Water Component of Flow.

Ground-Water Withdrawal and Use

Data on ground-water use were obtained chiefly from published reports (66, 71, and 91), and unpublished data from the files of the Geological Survey. Water-use data compiled in May 1967, as a part of the 1967 National Assessment of the Water Resources Council, were also used. The data were adjusted to represent conditions as of 1970, the level of development selected for other hydrologic factors. The data, which are summarized in table 14, were developed early in the study for use in appraising ground-water withdrawal and consumptive use in relation to the natural recharge and discharge, and the availability of ground water. Data on water use presented in the functional appendices, particularly in Appendices IX and XI, were developed later, in some cases using different definitions and assumptions. The data presented in the functional appendices are considered to be the official-use figures for the study.

Total annual ground-water withdrawal is estimated to be about 5.0 million acre-feet as of 1970, of which about 3.8 million acre-feet (76 percent) is for irrigation and 0.5 million acre-feet each is for industrial use and public supply.

Table 14 - Summary of Estimated 1970 Ground-Water Withdrawal and Use

(Withdrawal and Consumptive use in acre-feet per year; all quantities in thousands)

Type of Use	Idaho	Mont.	Nev.	Oreg.	Utah	Wash.	Wyo.	Total
Irrigation								
Acres	922	16.5	0.85	151	0	150	0	1,234
Withdrawal	2937	50	2	369	0	438	0	3,796
Consumptive Use	1569	25	1	210	0	223	0	2,028
Industrial 1/								
Withdrawal	110	20	0	191	0	181	2.3	504
Consumptive Use 2/	5.5	1	0	9.5	0	9.0	0.1	25
Public Supplies								
Persons Served	402	56	0	321	0	1097	2	1,878
Withdrawal	110	14	0	74	0	298	0.4	496
Consumptive Use 3/	22.0	2.8	0	14.8	0	60	0.1	100
Rural-Domestic								
Persons Served	281	95	1	535	0	716	1	1,629
Withdrawal 4/	30.6	10.6	0.1	59.5	0	80.4	0.1	181
Consumptive Use 5/	15.3	5.3	0	29.8	0	40.2	0	90
Stock								
Withdrawn and Used 6/	11.1	1.3	0.25	5.4	0	14.3	0	32
TOTAL WITHDRAWAL (rounded)	3200	100	2	700	0	1000	4	5,000
TOTAL CONSUMPTIVE USE (rounded)	1600	35	1	270	0	350	0	2,300

1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

Consumptive use, in this report, includes not only the water returned to the atmosphere as vapor by the plant or animal for which it was withdrawn, but water transpired by nonbeneficial vegetation or evaporated from the soil incidental to use. Except for irrigation, the quantity of water used consumptively was taken as a percentage of the quantity withdrawn; the percentages ranging from 5 percent for industrial use where large volumes of water are used in washing processes, air conditioning, and waste disposal, to 100 percent for stock water. Total annual consumptive use of ground water is estimated to be about 2.3 million acre-feet as of 1970, of which nearly 90 percent is by irrigation.

In most of the region the ground water that is withdrawn but not consumed either discharges into fresh surface water bodies or percolates into aquifers. Exceptions are in Subregions 10 and 11 where part of the unconsumed ground water discharges into the Pacific Ocean or Puget Sound. Thus, depletion of the total annual water yield of the region by ground-water withdrawal is little more than annual ground-water consumptive use. However, as only part of the unconsumed ground water returns to aquifers, net ground-water withdrawal (consumptive use plus return to surface water bodies) is considerably larger than consumptive use alone. Net ground-water withdrawal probably is between 3 and 4 million acre-feet as of 1970.

Ground-water withdrawal is summarized by type of use and subregion in table 15. Irrigation use is by far the greatest in subregions east of the Cascade Range and the greatest concentration of use is in the Snake River basin (Subregions 4 and 5). There is also considerable withdrawal for irrigation in the Willamette Valley (Subregion 9).

Table 15 - Summary of Estimated 1970 Ground-Water Withdrawal by Type of Use and Subregion

(Withdrawal in thousands of acre-feet per year)

Type of Use	SUBREGIONS												Regional Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Irrigation	137	180	65	2400	525	35	190	8	150	15	30	60	3795
Industrial	31	15	9	64	41	7	61	112	100	21	36	6	503
Public Supply	110	32	38	50	47	26	28	16	28	18	100	2.5	495
Rural-Domestic	20	12	14	14	13	8	8	6	39	17	31	0.5	182
Stock	1.9	3.3	2.4	6.1	3.5	1.2	0.9	0.4	0.4	0.2	4.6	0.1	25
TOTAL (rounded)	300	240	130	2530	630	80	290	140	320	70	200	70	5000

Industrial supplies in this report include only self-supplied industrial withdrawals. The greatest concentration of ground-water withdrawal for self-supplied industrial use is in the Vancouver-Camas area and the Willamette Valley (Subregions 8 and 9).

Public supplies, in this report, include publicly and privately owned supplies serving the public in incorporated and unincorporated places and include utility districts, cooperatives,

associations, and similar group users. Public supplies are utilized for domestic, commercial, industrial, and other uses. Ground-water withdrawals for public supply are fairly well distributed through the region, but withdrawals are greatest in the Spokane Valley and the Puget Sound area (Subregions 1 and 11). A large part of the water withdrawn is used for industrial purposes.

Net ground-water withdrawal was estimated to be between 3 and 4 million acre-feet a year; or 3 to 4 percent of net annual recharge. However, most of this withdrawal is from the major aquifers, the younger groups, 1 through 5, which have a total gross annual recharge and discharge of about 78 million acre-feet. Some ground water also cycles through these aquifers more than once before leaving the region, especially in Subregion 4, and net annual recharge and discharge of these aquifers may be about 70 million acre-feet a year. Thus, net ground-water withdrawal is 4 or 5 percent of net annual recharge to and discharge from the major aquifers.

Future Availability

In the preceding section of this report it was estimated that net annual recharge to and discharge from major aquifers in the region was about 70 million acre-feet, and that present (1970) net annual ground-water withdrawal was only about 4 or 5 percent of that amount. It must not be assumed, however, that all of the unused ground water can be made available for use. Most of the ground-water discharge included in this estimate enters the streams of the region and is a part of the measured or estimated surface outflow from the region. However, development and use of additional ground-water supplies can add to the total available supply of the region in two different ways: (1) Ground water can be developed from alluvial and glacial deposits adjacent to the Pacific Ocean and Puget Sound in Subregions 10 and 11. Ground water intercepted in this way adds to the total available supply because it would otherwise have discharged into and mixed with salt water. (2) In many areas, large volumes of ground water are discharged by non-beneficial vegetation or evaporation from the water table. Lowering the water table could result in the addition of several acre-feet of water per acre to the usable supply in some areas. The water table is near the land surface in large areas in each of the 12 subregions. No quantitative estimate was made, because of the many assumptions that would be required, but undoubtedly the potential additional water supply that could be made available in this way is several million acre-feet annually. Large losses by evapotranspiration occur in nearly all valleys, and are especially significant in the Puget Sound Basin, Willamette Valley, and in the Snake River Basin in the Boise-Ontario area. Thus, although increased ground-water development in those areas would be balanced, in part, by a reduction in ground-water discharge to streams, a substantial part of

the withdrawal would be balanced by a reduction in evapotranspiration losses.

Although the use of ground water can add to the total annual water supply only in the two ways described above, the water supply available during low flow periods and at times of maximum use is far more critical to development than the total annual quantity available. The low flow of many streams occurs in the period July-September and the time of greatest consumptive withdrawal, which is largely for irrigation, is during the same period. Utilization of existing ground-water supplies and underground storage space to augment the supply of water available during those critical periods offers great possibilities. Some of the ways that ground water can be utilized to augment the available water supply are outlined below.

Although consumptive withdrawal of ground water generally decreases surface outflow from the region as described previously, at many places the reduction in surface flow is in streams where flows are uncommitted with respect to downstream consumptive use. Pumping from aquifers in the Snake River Plain downstream from Milner Dam, aquifers discharging into the Columbia River, aquifers in the lower Yakima Valley, and aquifers in several other major valleys would utilize ground water that would otherwise discharge into streams below points of major consumptive withdrawal. Furthermore, in some parts of most of these valleys, water logging is a problem and pumpage of ground water would help to alleviate that problem.

Ground water can be used to augment the available supply, even in basins where the aquifers are interconnected with a stream that is fully committed during critical low-flow periods, because the reduction in streamflow during the critical period is less than the quantity of water obtained by pumping. If a water-table aquifer and a stream are hydraulically connected, part of the discharge of a well near the stream consists of water diverted from the stream. The diversion can be either by diminution of ground-water accretion to the stream or by a movement of water from the stream into the aquifer and toward the well. (158) Many factors affect the proportion of water that is diverted from the stream at a particular time, but in a given basin, the percentage of water diverted by pumping from a well is related to the distance of the well from the stream. The maximum effects of pumping lag behind withdrawals and, where wells are one to several miles from the stream, the maximum effect may lag by several weeks to several months (figures 24a and 24b). Thus, pumpage of 1,000 acre-feet of water from a river basin during a 90-day irrigation season might reduce surface outflow from the basin by only 100 or 200 acre-feet during that season, the remainder of the water withdrawn coming from storage. The depleted ground-water storage would be replenished during subsequent months when recharge and streamflow are greater and consumptive-use requirements

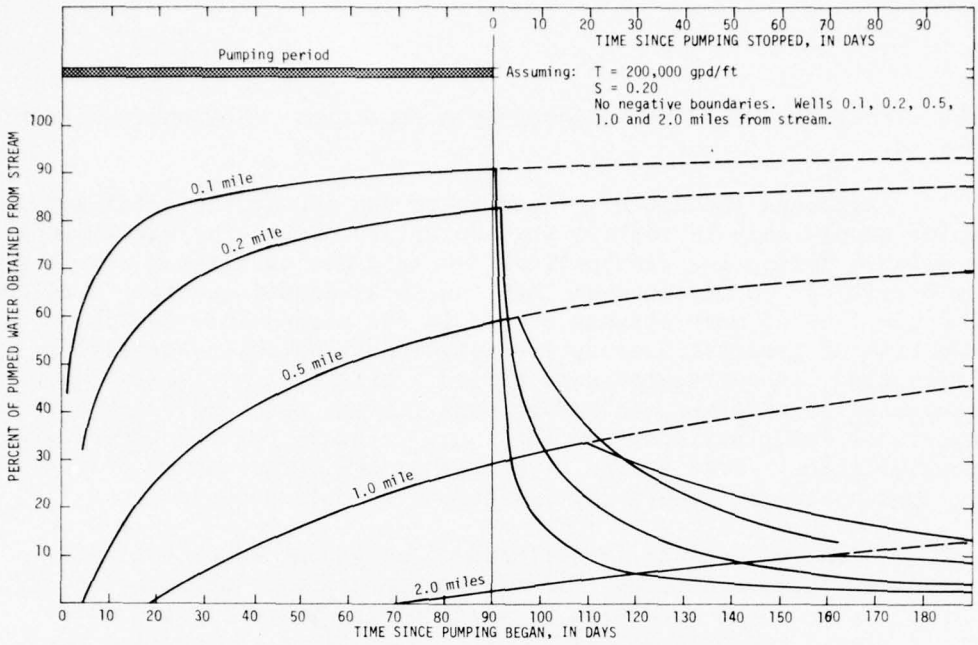


Figure 24a.--Effect of Pumping on the Flow of a Nearby Stream.

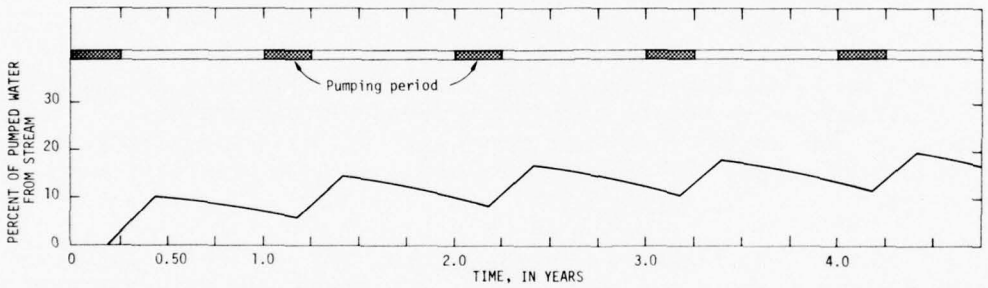


Figure 24b.--Cumulative Effect of Seasonal Pumping on a Well 2 Miles From a Stream.

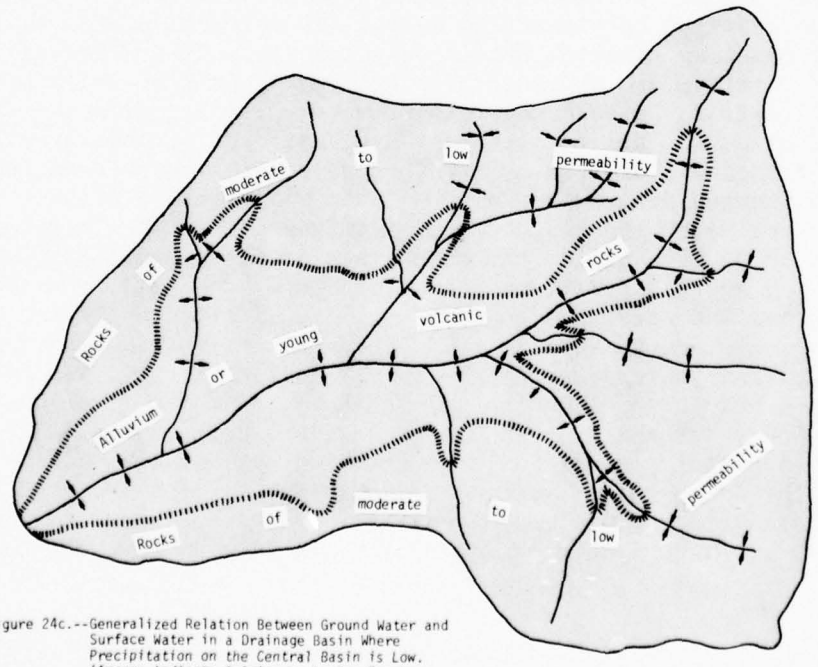


Figure 24c.--Generalized Relation Between Ground Water and Surface Water in a Drainage Basin Where Precipitation on the Central Basin is Low. (Arrows indicate Gaining or Losing Reaches of Streams.)

are low. The theoretical effects on streamflow caused by pumping wells, for a period of 90 days, at various distances from a stream are illustrated in figure 24a. The theoretical effect caused by cyclic pumping of a well 2 miles from a stream is illustrated in figure 24b. For computing these effects, the usual idealized conditions were assumed, and the coefficients of transmissibility and storage were assumed to be 200,000 gpd per foot, and 0.20, respectively. Lowering of the water table may induce additional recharge from other sources and reduce evapotranspiration waste, thus the reduction in ground-water storage and diversion from the stream would be less than is indicated. However, a nearby negative boundary, for example rock of low permeability cropping out in the valley wall, would cause a greater diversion from the stream than indicated.

In many basins some potential recharge is rejected in the late winter and spring, and where this happens the aquifer might completely refill under the changed regimen and the cumulative effects suggested by figure 24b might not occur.

Conjunctive use of surface and ground water offer great possibilities for future irrigation developments. In many irrigation projects water logging has become a problem. Aquifers in areas of future projects are fairly well known and the projects could be planned to obtain only part of their supply from surface sources--ground water being utilized as a supplemental source. Thus, not only would smaller diversions of surface water be needed, but also the water table could be maintained at a reasonable depth.

The water supply available during critical periods can also be enhanced by artificial recharge with water that is surplus to needs during other periods. This is discussed in the section entitled "Artificial Recharge."

In semiarid plateaus of southeastern Oregon, southwestern Idaho, and Nevada, there is little or no surplus water available at any time for artificial or induced recharge. Lowering the water table will result in reducing evapotranspiration waste where the water table is very shallow, but beneath much of those areas the water table is many hundred feet below the surface. Development to date has been small, and appreciable lowering of the water table has occurred only in a few small areas. Many additional large-yield wells can be developed without undue lowering of the water table provided the wells are properly spaced. Average annual recharge is probably less than 1 inch over a large part of those plateaus and the quantity of water in storage in the upper 100 feet of the saturated zone is many times the annual recharge. A limited amount of mining is necessary and inevitable in developing this ground-water supply.

Artificial Recharge

Artificial recharge may be defined as the planned addition of water to an aquifer to increase the supply of water in storage so that (1) at some future date more water can be withdrawn than would otherwise have been available, or (2) the same quantity of water can be withdrawn with a lesser pumping lift. To be effective, recharge must be with water that would not have reached the aquifer through natural processes, or that would have reached it at some other place where the recharge would have been less advantageous. Although recharge incidental to irrigation with surface water diverted to an area may be very beneficial to the ground-water supply, such recharge generally is not regarded as artificial recharge because the primary objective is to raise crops rather than to build up the water table. This type of incidental recharge has increased the ground-water supply and the base flow of streams at many places in the region, particularly in southeastern Washington and southern Idaho.

Artificial recharge does not add to the total water supply but does add to the supply available during periods of low water yields by allowing utilization of water stored during periods of surplus. With adequate hydrologic data and proper planning, artificial recharge can be a major element in the effective utilization of the total water resource.

There are two general methods by which artificial recharging is accomplished; by water spreading, and through injection wells. Water spreading is effective where surficial materials are at least moderately porous and permeable and percolation to the aquifer is not prevented by layers of impermeable material. Injection wells can be utilized where surficial materials have low porosities and permeabilities, where the surface areas needed for water spreading are too costly, or where the aquifer is isolated from surficial deposits by strata of low permeability. Experiments on water spreading and the feasibility of recharging aquifers underlying the Snake River Plain are described by Mundorff (81). Experiments on recharge through injection wells in basalt at Walla Walla and The Dalles were described by Price (122), and Foxworthy and Bryant (33), respectively.

Artificial recharge is being done on a small scale at a few places, and the known operations are described briefly in the subregional sections. Most of this information was obtained from a report by Price, Hart, and Foxworthy (125).

Ground-Water Rights

All the states in the region have some type of water law recognizing that ground water in the state is public water, and

providing for appropriation of ground water for beneficial use under state regulation.

Idaho

The ground-water code of Idaho, declaring that "ground waters are public waters" was adopted in 1951, and requires that the ground-water resources of the state "be devoted to beneficial use in reasonable amounts through appropriation . . ." The right to the use of ground water may be acquired only by appropriation, which may be perfected by means of diversion and application to beneficial use, or by means of the application, permit, and license procedures provided in the act. The drilling and use of wells for domestic purposes were not affected by the law, except for providing inspection of the wells by the state. The application, permit, and license procedures are not compulsory; the procedures are used primarily to establish date of priority. The administration and enforcement of the ground-water code is the duty of the State Reclamation Engineer. No compilation of ground-water rights has as yet been made for the State of Idaho.

Montana

The Montana code of 1947 and the supplemental code of 1961, provide for the appropriation and regulation of ground water. Ground water is defined as "any fresh water under the surface of the land . . ." Beneficial use is the extent and limit of the appropriative right. An appropriation of ground water, after January 1, 1962, is made by filing a notice of appropriation and a notice of completion with the County Clerk. Appropriative rights relate only to the quantities of water for beneficial use and not to water levels, means of use, or ease of withdrawal; and appropriative rights shall not apply to minimal household use.

Provision is made in the code for filing a "declaration of vested ground-water right" where ground water had been put to beneficial use prior to January 1, 1962.

Nevada

Nevada water laws declare that all underground waters within the state belong to the public and, subject to all existing rights, can be appropriated for beneficial use only under the laws of the state. Laws governing appropriation from an artesian or definable

aquifer were effective March 22, 1913, and those covering percolating water, "the course and boundaries of which are incapable of determination," were made effective March 25, 1939. Vested rights acquired before enactment of the ground-water laws are recognized. The State Engineer is responsible for administration and enforcement of the water laws.

Oregon

Oregon water laws recognize that all water within the state from all sources belongs to the public. Subject to existing rights and special provisions and withdrawals, all waters within the state may be appropriated for beneficial use. The Ground-Water Act of 1955, which applies to the entire State of Oregon, repealed the underground-water laws which had been in effect in that part of Oregon east of the summit of the Cascade Range since 1927. The act provided a means for registration of all claims of rights to appropriate ground water by virtue of use initiated before the effective date of the laws, and provides for later adjudication of the rights claimed to determine the quantity and priority of each right.

A legal right for an appropriation of ground water initiated after August 3,1955, can be established only through beneficial use under the provision of a ground-water permit issued by the State Engineer except for stock watering, small domestic, commercial, and industrial supplies, and lawns and gardens not exceeding one-half acre.

The State Engineer's office administers the water laws in Oregon. As of March 1967, primary water rights for 7,611 wells were on file with that office. Primary rights allow withdrawal of 1,266,546 acre-feet annually, of which 635,268 acre-feet (50 percent) is for irrigation of 235,581 acres. Subregion 9, the Willamette Valley, has more than 70 percent of the wells, and, in terms of quantity of water, 56 percent of the municipal rights, 51 percent of the industrial rights, and 57 percent of the irrigation rights.

The maximum rate of withdrawal allowed by primary water rights, during the summer irrigation season, is 3,610 cfs--about 1,620,000 gpm. Data are not available on supplemental ground-water rights.

Utah

Utah water laws state that all waters within the state, whether above or under the ground, belong to the public subject to all existing rights. Rights to the use of unappropriated public waters are acquired only by application to the State Engineer. The appropriation must be for some useful and beneficial purpose.

Washington

The laws in the State of Washington relating to ground-water appropriation were enacted in 1945 and essentially extend the procedures of the surface-water code to the appropriation of ground waters. Withdrawals for various uses not exceeding 5,000 gpd were excluded from the provisions of this act. To accommodate ground-water users claiming vested rights through developments established prior to 1945, a provision was made for a declaratory period of 5 years during which such users could acquire a water right through a declaration of their claim. Ground-water rights may also be established through adjudication procedures.

The Department of Water Resources administers ground-water appropriation laws in Washington and, as of September 30, 1966, there were 7,585 active ground-water right records on file with that agency in the form of appropriation permits and certificates and declaration certificates. A total of 1,087 of these has been perfected through the declaration of claim procedure.

The active prime ground-water rights throughout the state, which may be exercised during the summer period, indicate a total allowable rate of withdrawal of 3,017,840 gpm (6,700 cfs). Nearly all this quantity, 3,014,290 gpm, is considered to be comsumptive to the ground-water resource. The remainder, 3,550 gpm, is classified as being partly comsumptive to the ground-water resource. Definitions of the terms consumptive and partly consumptive are as follows:

Consumptive Ground Water

> All withdrawals are considered to be consumptive unless the full amount of the withdrawal is returned to the source aquifer(s). [Heat-pump use is consumptive if the water is not returned to the source aquifer(s) but is returned to some other aquifer(s). Also if ground water is discharged to a surface-drainage system, the withdrawal is consumptive.]

Partly Consumptive Ground Water
Where the full amount of a withdrawal is returned to the same source aquifer(s).

In addition to prime right quantities, a total of 39,535 gpm (88 cfs) has been appropriated under supplemental rights.

Annual withdrawal limitations have been specified for nearly all ground-water rights, and, in total, 1,710,650 acre-feet are authorized for withdrawal under prime rights and 502,016 acre-feet are allowed to be withdrawn under supplemental rights from ground-water sources in the State of Washington.

All water-right quantities in the State of Washington have been summarized by location in geographic units called "Water Resource Inventory areas." These areas are shown on maps in the subregion reports and their relationship to the Columbia-North Pacific subregions is discussed in the Regional Summary section on surface-water rights.

Wyoming

According to Wyoming laws, both surface and ground water are the property of the state. Water rights are acquired only for beneficial use of water. Water laws are administered by the State Engineer. The laws provide for registration of vested ground-water rights for wells drilled before April 1, 1947, where water from the wells was beneficially used.

RELATION BETWEEN SURFACE AND GROUND WATER

Ground water and surface water are not separate resources; they are both component parts of the total water resource. As has been explained in earlier sections of this report, the interrelations are such that ground-water supplies cannot be added to water measured in streams to get a total supply; and in many basins, water may interchange several times between the aquifers and streams before leaving the basin. The importance of the ground-water component of streamflow has been emphasized.

The quantity of ground water discharging into a stream is related to the gradient of the water table near the stream, which, in turn, is dependent, in part, upon river stage but is also related to changes in the water table. Water-table changes are related to seasonal changes in recharge from precipitation, irrigation

percolation, or other sources. In humid parts of the region, where recharge is from precipitation, the water table generally is highest, and ground-water discharge is greatest, during the winter or spring months when streamflow is relatively large. Ground-water discharge is least in the late summer and fall when water-table gradients are low and streamflow also is low. Where recharge is chiefly from snowmelt, the water table is highest in the late spring and summer, and ground-water discharge is greatest during those periods. The ratio of ground water to surface water in the stream becomes progressively greater as the discharge of the stream declines and, in most unregulated streams, the ground-water component of streamflow is close to 100 percent for varying periods nearly every year.

In the mountainous parts of the region which receive moderate to large quantities of precipitation, ground water is effluent practically continuously and throughout the entire reaches of many streams. Most of the exceptions are in the Cascade Range where some streams are underlain by exceedingly permeable rocks and lose water through certain reaches.

East of the Cascade Range many tributary streams lose part or all of their flow as they traverse semiarid or arid basins underlain by permeable deposits. In turn, the trunk streams draining those basins receive large quantities of ground-water inflow especially at the lower ends of the basins. These relations are shown in a generalized sketch of a drainage basin in figure 24c. West of the Cascade Range recharge from precipitation is large enough in the alluvial basins, such as the Willamette Valley and Puget Sound Basin, that aquifers are effluent to most streams most of the time.

The effect of pumping wells in an aquifer hydraulically connected to a nearby stream was discussed in the section headed "Future Availability."

NEEDS FOR ADDITIONAL HYDROLOGIC DATA

Adequate basic data are an essential prerequisite to understanding and evaluating the total supply of water available, both surface and ground, and the effect that increased use will have on the quality of the supply. In many parts of the region adequate data are not being collected to define existing conditions, to determine changes in quantity or quality, or to complete meaningful analyses.

Climatologic Data

The network of climatologic stations, about 560 in the region, is adequate only for general inventory and study of the water

resources. Most of the stations are located at low altitudes. Detailed study of specific problem areas will require a denser network of stations in those localities. The great geographic variability of climatological elements, such as is found in the mountain and arid areas of the region, indicates the desirability of increasing the number of climatic stations. The Puget Sound Subregion can be cited as an example of data deficiency. About 35 percent of the temperature and precipitation stations are at altitudes less than 100 feet above sea level, 60 percent are less than 500 feet, and 90 percent are less than 2,000 feet. This provides fair coverage for most lowland areas, but is inadequate in the foothills and mountains where precipitation varies markedly from point to point. The mountain areas, however, are sparsely inhabited and, for the most part, inaccessible to surface travel. Operation of climatologic stations in such areas is both difficult and costly. Because of these obstacles, consideration should be given to developing more new equipment that will operate unattended for extended periods of time. A telemetry system to transmit real-time climatological data from remote areas is needed.

Wind and evaporation data have been collected at only a few locations; about 40 stations are presently active, and again mostly at lower altitudes. Additional information is needed in the mountains and at other inland locations to better define wind movement and evaporation. Data on other parameters, such as humidity and sunshine, are sparse. Evaporation data for open-water surfaces are needed to supplement data on evaporation from pans.

Detailed isohyetal maps should be developed for all of the 12 subregions.

The Climatological Handbook, prepared by the Meteorology Committee of the Pacific Northwest River Basins Commission, presents tabularized observed and statistically arrayed data for the records of climatic factors collected to date. Updating of this information will be needed periodically.

Streamflow and Stage

The two principal types of gaging stations in a streamgaging network are hydrologic and project. Hydrologic stations, identified as primary and secondary, are used to obtain the stage and discharge data needed for general water resources inventory and planning. Primary hydrologic stations are intended to run indefinitely and, by showing long-term trends, they furnish the key to general coverage of the region. Secondary hydrologic stations are intended to be operated only long enough to establish the flow characteristics of the watersheds they gage, relative to one or more of the primary hydrologic stations. Project stations are those used for the

operation of an existing project, the design of a proposed project, or for administrative or legal purposes. Often a single station may serve as both a hydrologic and a project station.

The network of primary and secondary stations is incomplete. Additional primary stations are needed to better define the runoff or discharge from many subbasins and subregions. Secondary stations are needed throughout the region to improve and expand the general knowledge of hydrology. The greatest deficiency in streamflow data is in tributary streams with small drainage areas, especially at the higher altitudes. These data are needed for all types of hydrologic studies. Because basic data needs change with time, the networks should be appraised periodically. The runoff from both large and small basins must be gaged in order to define low, mean, and high flows under the varied geologic and climatologic conditions in the region. For example, about 90 percent of the area of a subbasin should be gaged in order to obtain a reliable estimate of the mean discharge from that subbasin. Also, some small streams similar to those found in the ungaged area must be measured in order to satisfactorily estimate discharge. Only about 60 percent of the coastal basin areas are gaged; also, only a very few of the high mountain small basins are gaged in the areas of intense precipitation. Stations near the mouths of large streams furnish data on total basin yield but do not show the variations in streamflow from place to place within the basin.

The crest-stage-gage, peak-flow programs in most of the states, along with the primary and secondary gaging programs, furnish considerable data for making flood-frequency and other high-flow studies. Present flood-frequency studies should be updated and special attention given to semiarid areas. There is a general lack of low-flow data, especially for small drainage areas where differences in geology and climate affect the low flows. Low-flow frequency studies would provide a basis for the design of water-supply and waste-disposal systems, for the maintenance of restricted-channel discharges, and for definition of the quantity of water available for fish propagation and supplemental irrigation.

Discharge records for a base period are often needed to make regional analyses of data. Because gaging stations are installed at different times for a variety of reasons, records covering the desired period of time are not always available. The missing record can be obtained using statistical methods and should be filled in for certain groups of stations that are commonly used in regionwide analyses.

The Geological Survey has started a system of putting most records of daily discharge in digital storage and computing certain statistical summaries. This system should be expanded to include all gaging stations in the region; also, all ground-water and quality-of-water data should be stored and made retrievable.

Analytical and interpretive studies should be made of climatic, physiographic, and geologic characteristics that determine basin yield. Land use, cultural practice, and methods for watershed-protection programs need critical evaluation relative to their effect on the natural basin runoff. Studies are also needed to define the effects of urban development on stream flow characteristics.

A better understanding of the principles of flow in many tidal estuaries is vitally important. Rates of fresh-water discharge, flushing, salinity intrusion, and many other tidal flow characteristics must be determined to resolve problems that arise with increasing use and development of tidal estuaries.

Little is known, and less has been published, on closed lakes and their changes in water level and chemical quality in response to changes in supply (precipitation and inflow) and losses (evaporation, leakage, and diversion). Such information should be assembled and correlated with runoff or climatological data.

The streamflow and modified-flow studies for the Columbia River Basin made by the Columbia Basin Inter-Agency Committee should be updated and the area expanded to cover the entire region. The data could be arranged to show where, when, and how much any selected record should be modified to make it comparable throughout.

Water Quality

Basic data, collected on a continuous basis from selected streams over the entire basin, are needed to define the existing situation and provide background information to detect and record changes in water quality. Limited programs of this type are now being conducted by the Geological Survey, in cooperation with state agencies in Idaho and Washington. The Geological Survey maintains seven irrigation network stations to evaluate the chemical quality of surface waters used for irrigation and the changes resulting from the drainage of irrigated land. It also operates three stations to monitor the amount of pesticides present in surface waters. The Federal Water Pollution Control Administration maintains a surveillance network of 14 stations to check water quality from the aspect of pollution to protect the quality for present and future uses. These programs provide reconnaissance data, however, and are not adequate to provide comprehensive understanding of all aspects of water quality. Especially lacking are data on fluvial sediment in the streams. Practically no information is available on this important parameter of water quality except that which has been collected in connection with small regional or specialized studies. Most of the sediment data collected prior to 1962 are unpublished.

The amount and relative ratios of the major dissolved ions

in surface waters, mostly the larger streams of the Columbia River Basin are generally known or can be fairly accurately predicted. However, few data are available on the minor constituents (metal ions such as zinc, copper, and arsenic; organics; herbicides and insecticides; phosphates; etc.) whose importance will be greater as water use becomes greater and more varied. In a cooperative program with the State of Washington, the Geological Survey has been collecting data on chromium, copper, zinc, and arsenic at about 100 stations since 1959. Similar comprehensive data on other minor constituents are not being obtained. Basic data on the occurrence and distribution of these constituents are needed now in order to provide a base for defining future water quality changes and water suitability as water use increases.

Studies have been made regarding the transport of radioactive materials by the Columbia River from Hanford, Washington, to the ocean. Monitoring of these radionuclides should be continued.

The adoption of water quality standards by the states presents a need for a surveillance program to assure that the established quality levels are maintained. A large monitoring program is needed to adequately determine the present water quality and to check against future degradation of water quality. The states will increase their surveillance network to assure compliance with, and maintenance of, the adopted water quality standards as the needs are defined. The parameters to be measured include temperature, bacteria, conductivity, pH, toxic material, oil and objectionable floating solids, turbidity, color, and dissolved oxygen.

Adequate data on the quantity and characteristics of stream sediments are required for power and flood control reservoir planning, control of the aquatic habitat, design and location of water intakes, developing the recreational use of water, and the evaluation of land treatment practices. Sediment data are sparse and the few existing sampling stations have been operated for only very short periods. Long-term continuous records throughout the region are needed to reflect the trends in sediment transport. The quantity, character, and rates of sediment yield should be defined; also, the geologic origin of the sediment and the mode and areas of deposition in the watershed. Natural stream channels adjust to flow and sedimentation, but alteration of these characteristics by control works may have beneficial or detrimental effects, depending upon local conditions.

Water temperatures are routinely being collected and published for only about 150 sites in the region. Other special purpose temperature data are collected by various agencies, but these data are not generally available. A great many more continuously recorded stream temperatures are needed over a period of time in order to develop reliable water temperature information and make areawide analyses to determine changes in water temperature.

Some specific water quality related studies needed to provide for future water resource development are the occurrence and characteristics of thermal springs; time of travel in relation to irrigation return flows, waste disposal, and pesticides; effects of irrigation use on the chemical quality of surface and ground waters; the compatibility of surface and ground waters in potential areas of artificial recharge; and the effect of liquid waste disposal into the ground.

Water Use

A complete study of water uses is needed that includes a concentrated effort to determine more accurately the use and withdrawal quantities for all water uses.

How water is used has a pronounced effect on the supply-demand relationship because some uses deplete the supply while others do not. The total supply immediately available is depleted by the quantity of water consumed, not by the quantity diverted; return flow may or may not be directly to the source of supply. In using water, man returns it either as vapor to the atmosphere or as liquid to the soil, ground-water reservoirs, or streams.

The principal consuming uses are irrigation, domestic, industrial, and thermal power. The main nonconsuming uses are navigation, dilution of wastes, fisheries, hydroelectric power, recreation, and for aesthetic appreciation. All data on water use--whether withdrawals, losses, onsite requirements, or in-channel requirements--contain an unknown margin of error originating in a variety of ways. Data on manufacturing, mining, and thermal power withdrawal and discharge are estimates rather than accurate measurements. Municipal withdrawal is usually metered at the source, but it is not adjusted for leakage and generally is not wholly metered at points of use. Accurate measurements of municipal sewage discharge normally are not available because of the uncertainty introduced by line leakage, line infiltration, and the mixing of storm-sewer and sanitation-sewer discharge. Data on irrigation and onsite losses involve specific assumptions as to rate of infiltration of water into the ground, as well as to evapotranspiration losses from reservoirs, main-conveyance channels, onfarm distribution channels, and fields. Most experimental data have been obtained from comparatively small plots; and errors undoubtedly occur when such data are extrapolated to larger areas. Very few data are available on withdrawals of ground water for irrigation. The source of water as well as the quantity diverted and consumed should be determined.

Ground Water

Geologic mapping of the entire region has not been completed and detailed ground-water investigations have been made only in limited areas covering about 10 percent of the region. However, most of the mapping has been done in the populated areas where needs are the greatest. General reconnaissance studies are needed to appraise the overall ground-water situation, followed by detailed investigations that include geologic mapping to identify geologic units and the water-bearing characteristics of the aquifers described in the general reconnaissance work. Although present ground-water withdrawals in most areas can be increased and new developments started simply by drilling wells, development of local ground-water supplies should be planned only on the basis of quantitative field investigations that incorporate exploratory drilling and aquifer testing. Such drilling and testing would permit a determination of hydraulic constants and an evaluation of the potential yield of the ground-water reservoir.

As a ground-water reservoir in a given subregion undergoes development, periodic measurements of water levels and chemical analyses of water samples are advisable for early detection of problems that may occur during the course of development. To collect such data effectively, a network of observation wells that are accessible for periodic sampling and water-level measurement should be established. Wells included in the observation program should be selected to reflect representative changes in water levels and chemical quality that might result from ground-water development of various aquifers and local areas. Observation wells are needed in areas near the coast to identify water-quality changes that would detect inland or seaward movement of the interface between fresh and salt water. Because of the possibility that domestic sewage and industrial wastes may contaminate shallow aquifers which, in turn, may pollute nearby streams, water-quality changes in these aquifers should be evaluated periodically.

In addition to the data obtained from the observation well network, newly drilled production wells can supply a large quantity of pertinent information, such as pump-test and well-completion data, drillers' logs, and chemical analyses. This information should be collected and filed at a central location. Many additional pumping tests are needed to determine the coefficients of transmissibility and storage of aquifers throughout the region.

In addition to the collection of various kinds of data, analyses of the data are needed. One badly needed study is that of complete aquifer systems. Such a study would include determining the source and quantities of recharge to the aquifer, the movement of water through the aquifer, volumes of water in the aquifer, a determination of how much water can safely and economically be removed

from the aquifer, and the natural and manmade means of removing water from the aquifer.

Ground-Water Surface-Water Relationships

Studies are needed to determine the ground-water component of streamflow, to show how the ground-water component varies with time, and to verify or devise methods of separating the streamflow hydrograph into its two major components, direct runoff and ground-water discharge. Rapidly increasing demands for water require a better understanding of ground water-surface water relations in order that the effects of changing patterns of development and a changing environment can be foreseen.

Time of Travel

Few time-of-travel studies have been made in the region and those mostly in Subregions 7, 9, and 11. Dispersion studies are equally important and the two are often made in conjunction with each other. The greatest need for these studies at this time is in regard to pollution from domestic and industrial wastes, thermal pollution, and the transport of radionuclides; other quality-of-water factors such as pesticides, dissolved oxygen, and sediment also are important. Time-of-travel studies should be made on all main tributary and mainstem streams; also on any small streams where pollution may be a factor. The investigations should be made at several river stages to evaluate the effects of high, low, and medium rates of flow.

Drainage Areas

The size of a drainage area is needed for any hydrologic study; however, the only drainage areas that are routinely published and available to everyone are those above gaging stations. In 1962, the Geological Survey, in cooperation with the State of Washington, published drainage-area data for western Washington, and in 1964, for eastern Washington. The minimum stream size required for listing was about 10 square miles at the mouth, although many smaller areas were shown because of other criteria for determining points of measurement. The publications were prepared in accordance with recommendations of the Federal Inter-Agency River Basin Committee which in 1951 designated the Geological Survey the coordinating office among agencies for the determination of drainage areas in most areas of the United States. Drainage-area publications, similar to those prepared for the State of Washington, are needed to cover the remainder of the Columbia-North Pacific Region.

TECHNOLOGICAL ADVANCES

New techniques in finding, developing, using, and conserving water supplies may make available, at reasonable cost, additional supplies that will be needed to help meet the increasing demand for water. Some of the techniques described will have only limited application, but may be very important locally when the supply problem is critical. Others, undoubtedly, will prove to be principal tools in increasing water supplies; these mostly involve principles that are already known but lack the perfection of economical techniques. Still others present unsolved problems that will require new technology or a breakthrough of present applications.

Forecasting

Daily, seasonal, and annual variations in natural hydrologic events place a high premium on accurately forecasting the quantity or rate of runoff in order to plan for best use of the resource.

The daily forecasts, by means of computer, determine streamflow for up to 30 days in advance from measurements of snow-water equivalent, air temperature, precipitation, soil moisture, antecedent conditions, and contributing area. Upstream contributions are combined and routed downstream to provide results at any point in the river. These forecasts are the bases for daily project operations.

Seasonal forecasts utilize similar parameters in multiple correlation equations to compute runoff for the year or portions of a year.

For hydrologic design, reasonable extreme values of the above parameters are commonly combined to yield an extreme value such as the probable maximum flood used in spillway design. Another principal tool used in hydrologic design is probability analysis. This method indicates the statistical probability that a given quantity of precipitation or runoff will occur at some future date; however, the year of occurrence cannot be predicted. Also, no one has been able to predict next year's precipitation on the basis of past trends.

In order to coordinate river forecasting activities in the Columbia-North Pacific Region on an operational basis, the Cooperative Columbia River Forecasting Unit was formed in 1963, under agreement made at the Washington level of the agencies involved. This unit, presently comprising river forecasting elements of the Corps of Engineers, North Pacific Division, and the Portland River Forecast Center, Weather Bureau, ESSA, provides the means to centralize forecasting and river regulation activities to meet the

requirements of both agencies. The overall objectives of the unit are: (1) to make best use of available computer facilities and trained river forecasting specialists of the agencies involved; (2) to advance techniques in all phases of river forecasting as related to river management; (3) to provide coordinated operational forecasts on a long-, medium- and short-range basis for the common use of both agencies in meeting their respective missions; and (4) to centralize the river intelligence in a river operation center for daily briefings. By meeting these objectives, the operation of the unit jointly by the two agencies has resulted in great efficiencies in Federal river operation by coordinating forecasts as required for specific agency use, and by preventing duplication of effort. Aside from the economies achieved, a forecasting unit of this type is an essential part of an integrated river management system for day-to-day regulation.

The present forecasting of streamflows is essential for efficient operation of the many river projects, and it is the guide for conserving water. Improvements in current forecasting methods will also produce savings in construction costs, industrial and agricultural operations, transportation, and activities of the general public.

Evaporation Suppression

When certain chemical compounds are applied to water surfaces, the quantity of water lost through evaporation is reduced. The presently used compounds are normal long-chain alcohols, such as hexadecanol, which are insoluble in water. When applied to a water surface they form a film 1-molecule thick. Wind is probably the most important factor contributing to the destruction of a monolayer because the wind compresses the film and washes it ashore. Heavy rains and winds may cause mixing and subsequent destruction of the monolayer. Multiple use of a reservoir or lake, especially water-based recreation, would cause attrition of the chemical. Tests indicate that the efficiency of a monolayer is a function of temperature and that one compound may be more desirable than another through certain temperature ranges.

Evaporation also can be suppressed by the injection of air into the water body. In one experiment, a reduction of 15 percent was obtained during the summer using air-bubbling methods which tended to eliminate thermal stratification and reduce surface temperatures.

Vegetation Management

Forests and other vegetation can be managed so as to increase the water yield and still protect the quality of the water.

Vegetation is one of the most important factors that influence the quantity and quality of water coming from a watershed. Manipulation of vegetation can produce additional water primarily by two means. The first is the reduction of evapotranspiration and the second is induced snow accumulation by changing the pattern of forest cover.

The increase in water yield by prevention of evapotranspiration losses is proportional to the amount of vegetation removed. The greatest potential for such increases is in those areas of heaviest precipitation, particularly where much of the precipitation occurs as snow. Under a wide variety of conditions, water-yield increases vary greatly between watersheds.

Recent studies have reported increases varying from 16 percent in the Colorado Rockies to 45 percent in the Oregon Cascades. It should be kept in mind, however, that these examples are far from conclusive. Present evidence indicates that these increases will taper off considerably after logging, especially as the area is revegetated. With much of the region's forest land ownership under some form of sustained yield management, timber cutting levels tend to stabilize throughout the years. Only in special cases would cutting be accelerated extensively to affect water yields. Since the result of the treatment would depend on the size of the area treated, only if wholesale areas were devegetated would the accumulated effect be measureable. Therefore, this practice has a much more significant local than regional effect.

Conversion of brushlands to grass and conversion of deep-rooted species and riparian vegetation to plants that use less water will increase water yields. However, because such areas are either limited in acreage or are located in low-precipitation zones with high evapotranspiration rates, the potential for water yield increases is not great. The phreatophytes (common water-loving plants), even though not abundant, consume a significant part of the summer water supply. Some of this water may be economically reclaimable. Phreatophytes may be removed by uprooting, mowing, or spraying with growth-retardant chemicals. An alternative method of reducing evapotranspiration is to remove the water supply by draining marshes or pumping wells to lower the water table below the root zone.

Any efforts to increase water yield by vegetative management should be scientifically planned so as not to create additional hazards such as deterioration of water quality or flood hazards. Increases in water yield as a result of vegetative removal will diminish unless the regrowth of new vegetation is inhibited.

East of the Cascade Range there is a real need to improve water quantity and timing of runoff while west of the Cascade Range the need is not quite so urgent. However, if the results of work performed by the Forest Service in the H. J. Andrews Experimental

Forest at Blue River, Oregon, (see 134-125 which shows significant increases in low summer flows) are applicable to other areas, increased water yields even on the west slope of the Cascade Range would be feasible.

Another phase of vegetation management that may develop in the future is the irrigation of forests to increase their growth rate. A combination of fertilization and irrigation can materially increase per acre yields of timber.

Subsurface Reservoirs

In many parts of the region, available supplies may be increased through more effective management of the ground-water reservoirs. Greater utilization of ground-water supplies cannot significantly add to the total water supply; however, it may result in an improvement in dependability as well as an increase in the part of the total supply that is available for use. The improvement in dependability accrues through the function of the ground-water system as a reservoir. The increase in available supply results from the salvage of water that otherwise would evaporate or discharge naturally without being put to beneficial use. In contrast to these benefits, the greater use of ground water depletes the total water supply to the extent that the additional ground water is evaporated, transpired, or transported outside the region or area of consideration.

Ground-water reservoirs can, in principle, be managed like surface reservoirs, but utilization of them has important advantages. First, the initial costs connected with management of subsurface reservoirs commonly are much lower than for surface reservoirs. Second, the ground-water bodies generally are not subject to evaporation and are less subject to pollution and to undesirable temperature changes. The general objectives of managing subsurface reservoirs are the same as for surface reservoirs--to deliberately manipulate the additions to, and the withdrawals or releases from, the water body so as to store water during times of excess for use during later periods of deficient supply. The techniques required, however, are quite different.

Effective management of some ground-water reservoirs, expecially those from which the withdrawals now are localized or are relatively small, would include the deliberate drawdown of ground-water levels to make space for additional recharge water that is available naturally or that could be made available artificially. In areas where the proper hydrologic conditions exist, this can be accomplished with little or no effect on streamflow during critical periods of surface-water use. Increased withdrawals may also conserve the supplies of ground water available

by reducing the nonbeneficial natural discharge from the ground-water bodies, such as evapotranspiration or seepage to streams during other than critical periods of their flow. Gradual reductions in nonbeneficial natural discharge are occurring now at many places where pumping of ground water is being increased.

Artificial recharge is the process of adding water to the subsurface reservoirs. One type of artificial recharge is surface spreading, which consists of diverting water from a stream and allowing it to flow over or stand upon permeable material so that it may infiltrate to the ground-water body. Spreading can be accomplished by simply flooding flat areas in which the water can be retained for substantial periods of time, by holding the water in artificially constructed basins or in natural ponds, or by directing the recharge water into ditches or furrows. A second method which is commonly used to artificially recharge aquifers is the injection of water directly into the aquifer through wells. Expected improvements in artificial-recharge techniques will enhance this means of augmenting the natural recharge. However, not all the water recharged artificially is recoverable.

A method of increasing the recharge to aquifers, at the expense of flow in adjacent streams, is the deliberate drawdown of ground-water levels in shallow aquifers adjacent to streams so as to induce or increase infiltration of water from the streams into the aquifers. This practice is fairly common and is used largely to obtain water for municipal and industrial supplies that requires less treatment than if it were taken directly from the streams. The gain in well supplies by this method, of course, is offset by a corresponding reduction in the flow of the affected streams. However, at places where the wells can be located sufficiently far from the affected streams, the influence of pumpage from wells may be delayed until after periods of low streamflow.

Glaciers

Of considerable importance to water users is the fact that glaciers retain a large part of the precipitation falling on them during the wet winter season and release this water during the hot, dry, late summer season when it is most needed. The opposite is true of nonglacier areas which release most of their water during the wet season and early summer. Also, during cold wet years, when not as much water is needed by irrigators and other consumers, glaciers tend to accumulate precipitation and grow, and during the hot, dry years they tend to release more than an average quantity of water. Thus, glaciers are naturally regulated frozen reservoirs. Figure 25 shows runoff and precipitation in 1960 at South Cascade Glacier in Washington.

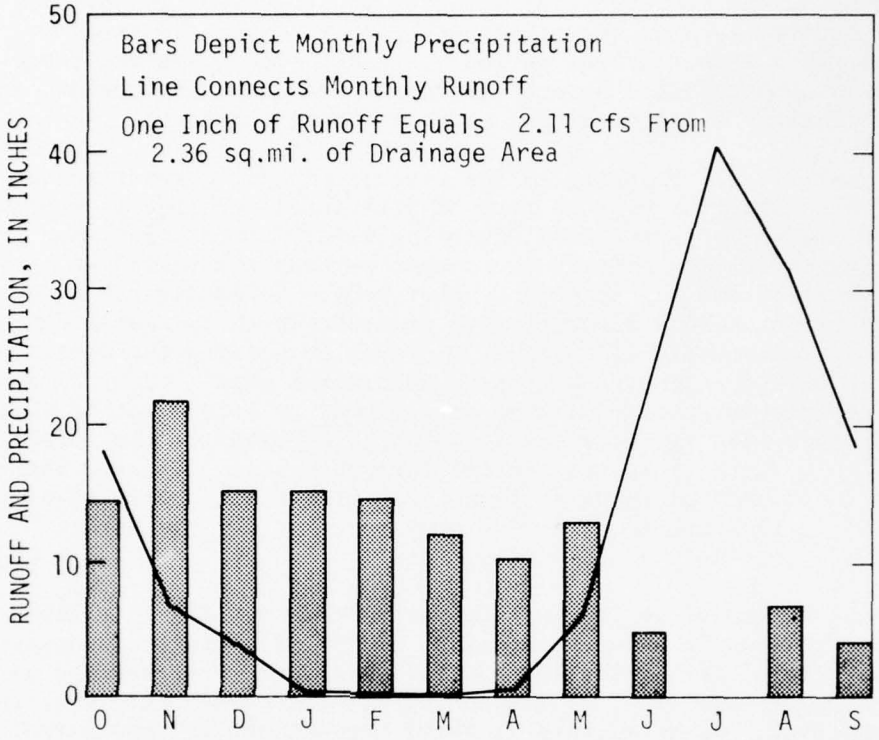


FIGURE 25. Runoff and Precipitation at South Cascade Glacier, Washington, 1960

The glacier-covered areas in the conterminous United States, consisting of 198 square miles, all lie in the 11 western states. (76) Forty-nine percent of the glacier-covered area is located in the northern Cascade Range in north-central Washington. The State of Washington claims 77 percent of the total surface area and the Columbia-North Pacific Region contains 83 percent of the total glacier-covered area. The glaciers are located in four states as listed in table 16.

The glaciers are estimated to contain 46 million acre-feet of water. If the melt rate were controlled to produce an additional 1 million acre-feet of water per year, the glaciers would disappear during the next 50 years. However, with 83 percent of the glacier area lying in the northern Cascade Range where water is presently plentiful, there is little likelihood that the glaciers will be depleted by man for water supply purposes.

It has been estimated that in 1850 the surface area of the glaciers in the region was about double what it is today. If it is assumed that volume is directly proportional to surface area,

then the gradual loss in volume of the glaciers contributed an average of 400,000 acre-feet of water per year during the last 100 years to about 1950. Since then the glaciers have remained fairly stable, neither growing nor shrinking appreciably.

Table 16 - Glaciers in the Region

	Surface Area (Sq. Mi.)	Surface Area (Percent of Regional Total)	Estimated Volume (Billion Gallons)	Estimated Volume (Acre-Feet)
Washington	153	92.8	14,400	44,200,000
Oregon	8	4.8	450	1,382,000
W. Montana	3	1.8	150	460,000
Wyoming	1	.6	30	92,000
TOTAL (rounded)	165	100.0	15,000	46,000,000

In theory, the melt rate of glaciers can be increased by spreading a thin layer, or decreased by spreading a thick layer, of dark material over the ice. Experience shows that the melt rate can be increased several times normal if the proper thickness of coal dust is applied; however, this is an expensive procedure. Glacier melt is caused chiefly by radiation from the sun, and coal dust reduces the reflectivity of the snow from about 50 to as low as 30 percent.

Most of the glaciers lie in National Park and National Forest wilderness or proposed wilderness areas where land-use restrictions would severely limit plans to control melt rates.

Alpine Snowfields

Alpine snowfields are an important source of summer streamflow in the region. There has been considerable experimental work on the use of artificial barriers to increase the depth and extent of alpine snowfields in order to increase both the quantity and duration of melt water released for summer streamflow.

Studies have shown that the size and depth of the snowfields are related to the size, shape, and orientation of the barrier behind which they accumulate. In many alpine areas natural catchments are filled early in winter and, once the natural barriers are full, the windborne snow of later storms is swept across the gently undulating snow surface to be deposited in the timber farther down the mountain. The melt water from this snow enters

the streams in spring when streamflow is high and must either be stored in reservoirs or allowed to run off to the sea.

Artificial barriers can be constructed at sites where drifting occurs naturally and thus induce additional drifting. Such barriers can be designed and located to increase the size of drifts that already persist most of the summer or to increase the depth of drifts that normally melt out by midsummer. The storage of water in high-altitude snowfields rather than in low-altitude reservoirs will result in a net reduction in evaporation losses.

Data from research studies and actual operations of artificial barriers indicate that a mile of snow fence will accumulate about 50 acre-feet of water in addition to that which would be on the site normally. Amounts will also vary with the site and fence height.

Breaking off cornices and inducing avalanches with subsequent accumulation of deep, protected drifts can also reduce evaporation losses and prolong snowmelt. The total supply of water may not be affected materially, although there may be some gain from reduced evaporation, but the redistribution of greater flows to the hotter, drier summer months is advantageous. One mile of cornice in the Colorado Rockies was estimated to contain 150 acre-feet of water after snow had disappeared from the surrounding areas.

In addition to barriers, various materials have been applied as film covers to maintain snowbanks until later in the season.

Weather Modification

Weather modification in its broadest sense includes all manmade changes in natural conditions of weather or climate. Cloud modification by artificial seeding with one or another of several agents has been extensively tested. The principal conclusion from these tests so far is that uncertainties still remain in the results and in the practical utility of present methods for artificially increasing rainfall.

The American Meteorological Society has stated that cloud seeding acts only to trigger the release of precipitation from existing clouds. The release of substantial quantities of precipitation by either natural or artificial means requires the preexistence of an extensive moisture supply in the form of moist air currents and of active cloud-forming processes. For this reason the meteorological conditions most favorable for the artificial release of precipitation are much the same as those which usually lead to the natural release of precipitation. This factor plus

the extreme variability of precipitation makes the evaluation of the effects of seeding difficult and often inconclusive.

In the June 1968 issue of Weatherwise, the American Meteorological Society stated, "In general we agree with the statement made by the National Academy of Sciences that there is increasing, but still somewhat ambiguous, statistical evidence that precipitation from some types of cloud and storm systems can be modestly increased or redistributed by cloud-seeding techniques."

In 1966, the National Academy of Sciences reported that precipitation increases in the order of 10 percent apparently can result from ground-based silver-iodide seeding of winter orographic storms. This conclusion refers specifically to winter mountain storms in the western United States.

The above discussion suggests that if any part of the United States can benefit from cloud-seeding, it should be the Columbia-North Pacific Region.

Nuclear Explosives

Detonation of nuclear explosives does not create water in quantity that significantly increases the supplies naturally available for use by man. However, nuclear explosives might be used to produce changes in the natural environments of water and thus have a useful application, but, as yet, their use for the enhancement of water resources is untested. They have a potential for (1) creating space in which water might be stored either on or beneath the land surface, (2) modifying the system of stream channels on the land surface, and (3) changing the transmissibility of rock strata underground. Although radioactive contamination can be predicted and controlled, it is an ever-present hazard that must be considered.

Surface storage of water, either temporarily for flood control or on a more permanent basis, could be accomplished using craters created by nuclear explosives. Another potential way of utilizing nuclear explosives for water storage is to create landslide dams. Choice of site and geology would be critical.

Underground storage can be provided by a nuclear explosion that is deep in soil or rock, yet close enough to the surface that the shattering effect reaches the surface. Water can then be diverted into the void created and stored with little loss by evaporation.

Obviously, there are many occasions where diversions of surface water are in order. Excavations of canals, changing of river courses, and draining of swamps are feasible by detonating

devices closely enough together that the craters form a continuous channel.

Underground movement of water may be either vertical or horizontal. Vertical percolation could be facilitated by perforation of impervious strata. Horizontal flow could be induced by blasting out impermeable intrusive dikes.

Recent studies by the Geological Survey indicate that it probably will be many years before nuclear explosives play an important role in water resources enhancement.

Desalination

The search for processes to desalinate saline and brackish waters has taxed the ingenuity of man for centuries and practical methods for desalination of ocean water in small quantities have been in use on ships for more than 100 years. The problems associated with desalination are primarily ones of engineering.

Low-cost saline-water conversion has made dramatic progress during the last few years. Conversion has advanced in a number of broad fields, each incorporating a different process. Some processes are distillation using fuels, solar-heat distillation, membrane processes, separation by freezing, and other chemical, electrical, and physical methods. The most advanced of the present processes is flash distillation.

Present developments indicate the use of large-scale, combination plants using atomic energy to provide both electric power and desalinized water. These plants would produce several hundred million gallons of fresh water per day and at the same time generate several million kilowatts of electric power. Such plants yield minimum costs for both commodities.

In 1967, Key West, Florida, completed the largest desalting plant to date. It produces more than 2.6 million gallons per day of fresh water at a cost of about 85 cents per thousand gallons.

A much larger plant, a dual-purpose power-desalting unit near Los Angeles, is in the planning stages for construction. The plant will deliver 150 million gallons of fresh water per day, enough to supply a half-million people, and at the same time generate enough electric power to serve two million people.

During the next 20 years costs may be as low as 10 cents per thousand gallons at a plant site. Even at this price, about $32 per acre-foot, irrigators could hardly afford to buy desalinized water. However, municipalities and industry could afford to pay

the price. Advanced technology using breeder reactors and improved distillation processes is projected to lower production costs.

If the need should arise, several large metropolitan areas in the region are strategically located for direct use of desalted water. Also, some inland areas, such as the Closed-Lakes Basin in Oregon, may eventually desalt water to supply fresh water needs.

At the present time some cities in the United States are desalinizing a certain percentage of their brackish water supply and mixing this with the untreated water to obtain water of an acceptable quality. This principle could be used in an area such as Subregion 12 where large supplies of brackish water are available. Also, some work is being done to develop crops more tolerant to salts, and studies are being made of irrigation practices that permit the use of brackish water.

The Department of Interior's Office of Saline Water stated in October 1968 that desalting is becoming more and more competitive with conventional sources of water supply and that comprehensive river basin studies must now consider desalting as an alternate source, either new or supplemental, of fresh water.



LOCATION MAP

SUBREGION 1

SUBREGION 1

CLARK FORK - KOOTENAI - SPOKANE

HYDROLOGIC FRAMEWORK

The Clark Fork-Kootenai-Spokane Subregion contains all of Montana west of the Continental Divide, northern Idaho north of and including drainages of the St. Joe and St. Maries Rivers, and that part of northeastern Washington containing the Spokane and Pend Oreille River Basins. It is bounded on the north by the International Boundary with Canada, on the east by the Flathead and Rocky Mountains, on the south by the Anaconda and Bitterroot Mountains, and on the west by the low divide of small Columbia River tributaries. The highest elevations in the area are along the Bitterroot Divide between Montana and Idaho, and along the Continental Divide in Montana. Ridge elevations along most of the Bitterroot Divide run about 7,000 feet above sea level, but, along the northern parts of the Continental Divide, ridge elevations reach 9,000 feet or higher in many places. Lowest elevations are found along the lower end of the Spokane River in Washington at about 1,300 feet.

Most of the mountain ranges in this subregion are aligned roughly southeast-northwest, and river drainages follow this orientation fairly well. But there are exceptions, particularly in central and eastern parts of the area, where mountain and river complexes change orientation rapidly within short distances. This mountain-valley character and the pattern of major divides and valleys, running generally SE-NW, have marked effects on weather, with large variations from west to east.

The subregion covers 36,361 square miles, of which 706 square miles are water and 35,655 are land, altogether amounting to about 13 percent of the regional area.

Figure 2 shows the general physiographic features of the subregion. Along most of the major streams and many of the minor ones are intermontane valleys and small prairies suitable for agriculture. In the upper basins, the floors of these valleys range in elevation from 2,700 to 4,000 feet and in the lower basins from 2,000 to 2,700 feet. These cultivable areas are separated by deep, narrow valleys and canyons where the streams cut through the numerous mountain systems. Mountains in the divide generally range from

7,000 to 10,000 feet. Two very important geologic events have determined the overall drainage pattern. The first event, which determined the main lines of drainage, was the early structural growth of the mountain ranges and valleys brought about by periods of folding and faulting, with intervening periods of erosion. The second event, which directly or indirectly altered many of the minor details of the drainage, was the advance of glaciers during the Pleistocene.

Streams originating within this subregion averaged about 14 inches of runoff per year or 36,253 cfs (cubic feet per second) during the period 1929-58. The maximum was about 1-1/2 and the minimum about 1/2 times the average.

The subregion is drained by three major river systems, the Kootenai, Clark Fork, and Spokane. Of the three, the stream gradients for the Kootenai are highest, but range from about 1 to 3 percent in the upper reaches and are only about 1/10 percent in the lower valleys. The Kootenai Basin contributes only about 11 inches of runoff per year in the United States, but about 18 inches are contributed by the portion of the basin in Canada.

The stream gradients for the Clark Fork Basin range from about 1 to 2 percent in the upper reaches and are only about 1/10 percent in the lower valley. The basin contributes about 14 inches of runoff per year, ranging from about 6 inches above Missoula to about 27 inches from the South Fork Flathead River drainage.

Stream gradients for the Spokane River Basin also range from about 1 to 2 percent in the upper reaches but are about 1/5 percent near the mouth. This basin contributes about 20 inches of runoff per year with the Coeur d'Alene River near Cataldo contributing about 27 inches.

Glaciers exist in the upper Flathead River Basin in sufficient extent to have an appreciable effect on the summer flows. However, the more important glaciers lie farther north in Canada.

Soils in great variety exist in the subregion, few of them residual in nature. Oldest soils are found on the upland plateau areas that were not disturbed by ice invasions. These soils were mostly airborne by prevailing westerly winds and contain volcanic ash from Cascade eruptions. Generally, the soils may be classified into three broad groups: light-colored upland soils, dark bottom land soils, and miscellaneous.

About 90 percent of the Kootenai, 80 percent of the Clark Fork, and 80 percent of the Spokane Basin are forest covered. The three main species are pine, fir, and Western Larch in nearly equal proportions, with the Spokane Basin predominately pine. The remainder of the subregion is agricultural land, mostly under irrigation in the Kootenai and Clark Fork Basins and dry land farming in the Spokane.

Spokane is the largest city, with a 1960 population of 181,608.

CLIMATE

Most of the weather variation is brought to this subregion on the general easterly flow of the lower layers of the atmosphere common to this latitude in the Northwestern United States. This general characteristic, however, is more pronounced in the northwestern parts (around Spokane, Coeur d'Alene, Bonner's Ferry, etc.) than in southeastern areas (around Butte, Deer Lodge, or even as far west as Missoula), probably because the mountain complex of western Montana and central Idaho is quite extensive and averages 1,000 feet or more higher than the mountains to the northwest, providing a partial shield from much of the weather carried in the general easterly flow.

For the northwestern fringes of the subregion, the only formidable mountain barrier upwind in the westerlies is the western Washington Cascade Range. Much of the time the resulting weather as far east as the Flathead Valley of Montana has Pacific Maritime characteristics - although much less pronounced than along Cascade western slopes. In western Montana this character becomes diluted by continental effects to the southeast, until in the Butte-Deer Lodge area, the climate has taken on many continental characteristics. During the cold half of the year, the valleys of the entire subregion experience many days with dense fog or low stratus clouds. This condition results from radiational cooling of valley bottom air, and relatively warmer Pacific source air moving over the top of the more dense air near the surface.

Precipitation

The precipitation varies widely with season, elevation, and location. The southwestern slopes of all mountain ranges have many Pacific precipitation features, but these characteristics diminish northwest to southeast. In general, the wettest areas are to the

north, but substantial moisture falls over most of the area with the exception of some "rain shadow" sections such as the Butte-Deer Lodge-Drummond valley, and a small area southwest of Flathead Lake. Aside from these mountain "shadow" relatively dry areas, the lowest average annual precipitation of the entire subregion is the section west to southwest of Spokane, where annual amounts average not far from 15 inches. Annual average totals increase rapidly, but not uniformly, eastward into the mountains. Several places in northern Idaho and extreme northeastern Washington have annual totals of 50 inches or more, and along the west slopes of the Glacier National Park Rockies annual totals increase to near 100 inches. The mountain "shadowed" sections of western Montana, however, have annual averages as low as 10 inches. Table 17 and figure 26 show precipitation data and location of precipitation stations.

Table 17 - Average Monthly and Annual Precipitation (inches), Clark Fork-Kootenai-Spokane Subregion, 1931-60

Station	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Kalispell WB AP	2,965	1.37	1.00	.96	1.04	1.67	2.21	1.04	1.09	1.04	1.24	1.43	1.33	15.42
West Glacier	3,154	3.13	2.42	1.81	1.87	2.36	3.02	1.27	1.33	1.89	2.64	3.06	3.26	28.06
Summit 1/	5,213	4.17	3.78	3.04	2.93	3.06	3.88	1.35	1.58	2.61	3.14	4.29	4.46	38.29
Polson AP	2,932	1.02	.97	.89	1.16	1.93	2.27	1.00	.94	1.23	1.29	1.17	1.16	15.03
Missoula WB AP	3,200	.92	.87	.73	.97	1.87	1.91	.85	.72	1.02	.99	.90	1.08	12.83
Drummond FAA AP 1/	4,240	.60	.55	.60	.74	1.80	2.11	1.14	.91	.93	.69	.71	.62	11.40
Butte FAA AP	5,530	.42	.44	.65	.90	1.74	2.42	1.20	1.03	1.04	.67	.49	.48	11.48
Libby 1NE RS	2,080	2.18	1.50	1.41	1.04	1.29	1.66	.62	.90	1.19	1.97	2.34	2.37	18.47
Mullan Pass CAA 1/	6,022	5.06	4.43	3.65	2.03	2.15	2.66	1.05	1.16	2.06	3.63	4.71	5.64	38.23
St. Maries	2,080	3.79	2.87	2.63	1.99	1.99	2.18	.71	.67	1.43	2.79	3.58	4.08	28.71
Coeur d'Alene RS	2,158	3.42	2.52	2.34	1.71	2.04	1.93	.66	.72	1.35	2.50	3.20	3.74	26.13
Bonners Ferry 1SW	1,846	3.16	2.24	1.76	1.11	1.37	1.62	.78	.78	1.26	2.41	3.08	3.51	23.08
Spokane WB AP	2,357	2.44	1.86	1.50	.91	1.21	1.49	.38	.41	.75	1.57	2.24	2.43	17.19
Newport	2,135	3.50	2.65	2.48	1.71	1.99	1.89	.61	.80	1.47	2.76	3.51	3.79	27.16
Metaline Falls 1/	2,107	3.14	2.48	2.08	1.76	2.32	2.98	1.40	1.30	1.62	3.06	3.15	3.37	28.66

1/ Period is longer or shorter than the 30-year normal.

In the northwestern parts of the subregion, a large proportion of the annual precipitation comes during the cold season (Spokane receives 70 percent of the annual normal during the October-March 6-month period). At the southeastern edge of the subregion, however, the picture is almost exactly reversed - 73 percent of Butte's annual normal comes during the April-September warm season. The change in seasonal maximum precipitation is fairly gradual northwest to southeast. Particularly over the mountains, most winter moisture falls as snow, and it is much heavier in all cases than over valley bottoms. Density of the mountain snowpack increases from about 20 percent water equivalent in early winter to about 35 percent in April.


B R I T I S H C O L U M B I A
BOUNDARY DAM
BOX CANYON DAM
Metaline
Ione
PEND OREILLE
BOUNDARY
Boulder Mountains
Bonners Ferry
Priest River
Priest Lake
Priest River
Newport
ALBENI FALLS DAM
Sandpoint
Pend Oreille Lake
Custer
Colville River
Pend Oreille River
Clark Fork River
Kootenai River
BONNER
LINCOLN
Libby
Cabinet Mountains
Cabinet Gorge Dam
Lake Pend Oreille
Eureka
Whitefish
Kalispell
FLATHEAD
Flathead Lake
Hungry Horse Reservoir
Flathead River
Swan Range
Mission Range
Mission Mountains
Jocko River
Jocko Lake
Post Falls Dam
Coeur d'Alene
Coeur d'Alene Lake
Coeur d'Alene Mountains
Thompson Falls
Thompson Falls Dam
Kellogg
Wallace
Missoula
Lolo Pass
Lolo Creek
Bitterroot Mountains
Bitterroot River
Bitterroot Range
Hamilton
Darby
Sapphire Mountains
Rock Creek
Flint Creek Range
Deer Park
Chattaroy
Little Spokane River
Long Lake
Nine Mile Falls Dam
SPOKANE
STEVENS
INCLINE
KOOTENAI
SHOSHONE
BENEWAH
SPOKANE
St. Maries
St. Joe River
St. Maries River
Spokane River
WASHINGTON
IDAHO
MINERAL
MISSOULA
RAVALLI
MONTANA
IDAHO
Base Rev. Oct. 1969



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL PRECIPITATION IN INCHES

CLARK FORK, KOOTENAI, SPOKANE SUBREGION I

1968

FIGURE 26

Temperature

The temperature regime follows the seasons very well, with cold winters (coldest in the higher valleys of the southeast), warm summers (warmest in the sheltered lower valleys of the northwest). Pacific modifying (warming) influences are at a maximum during winters in the northwest, where Arctic cold invasions occur only about once a winter, and at a minimum in the Butte-Deer Lodge section where cold continental air may penetrate several times in a winter. In the lower elevations from the northwest into the Thompson Falls-Libby section of Montana, highest temperatures of record run near 110°F., while Butte and Deer Lodge have reached only 100°F. (table 18) On the cold end of the scale, differences in extremes are greater; from around -50°F. in the Deer Lodge Valley to around -20°F. in much of northeastern Washington. Table 18 and figure 26 show temperature data and location of weather stations.

The longest growing season between occurrences of 32°F. temperatures is 175 days at Spokane. That for Polson, Montana, is almost as long at 142 days, whereas Libby and Butte, Montana, experience seasons of only 80 and 81 days, respectively. The average date of the last spring freeze is April 20 at Spokane, May 10 at Polson, and June 8 at both Libby and Butte. The average dates of the first fall freeze for these stations are, respectively, October 12, September 28, August 27, and August 28.

Wind

Windiness is quite variable; but most valley areas have less than 10 mph average wind speeds for the year. Some of the deeper, more sheltered valleys of the Kootenai, Clark Fork, and Flathead Rivers probably have annual average wind speeds as low as 5 or 6 mph. According to a statistical study by the Bonneville Power Administration, sustained (1 min. or longer) wind speeds may reach 70 mph about once in 50 years over all the subregion except in the southeastern part (Powell, Deer Lodge, Silver Bow Counties, Montana; and Kootenai, Benewah, and Shoshone Counties, Idaho) where extremes may reach 70 to 80 mph for the average 50-year return period.

Evaporation

Annual evaporation from a Class A pan is estimated at 35 to 40 inches over much of the area, but increases to 45 to 55 inches in the lower elevations in Washington.

Table 18 - Average and Extreme Temperatures (°F.), Clark Fork-Kootenai-Spokane Subregion

Station	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Kalispell WB AP	Av. Max.	27.6	34.2	40.3	53.6	64.6	70.6	81.2	79.0	69.5	54.5	38.8	32.3	53.9
(11)	Av. Min.	12.0	16.3	21.1	31.1	39.3	44.8	48.4	46.9	39.4	31.5	23.4	19.0	31.1
	Mean	19.8	24.5	31.8	43.7	52.2	58.6	65.7	63.1	54.7	43.9	31.0	25.0	42.8
	Highest	53	53	64	83	89	96	104	96	94	79	64	51	104
	Lowest	-38	-36	-29	10	19	28	33	31	23	16	-28	-22	-38
Summit 1/	Av. Max.	23.4	28.1	33.8	45.0	55.7	62.2	73.1	71.4	60.9	49.4	33.4	27.9	47.0
(23)	Av. Min.	7.2	10.7	13.6	23.3	30.8	37.2	40.3	38.5	33.5	29.2	18.6	13.1	24.7
	Mean	15.3	19.4	23.7	34.2	43.3	49.7	56.7	55.0	47.2	39.3	26.0	20.5	35.9
	Highest	48	56	62	74	78	88	93	96	91	82	61	57	96
	Lowest	-55	-43	-42	-30	9	15	26	19	6	-7	-42	-43	-55
Polson WB AP	Av. Max.	30.3	34.9	44.1	55.4	64.8	72.4	82.2	80.3	68.5	56.4	41.8	34.3	55.5
(47)	Av. Min.	17.8	20.4	26.6	34.0	40.5	47.4	52.8	51.3	43.9	35.7	27.6	22.9	35.1
	Mean	25.1	27.7	35.1	45.1	53.1	59.7	67.4	65.7	56.9	46.3	34.6	29.7	45.5
	Highest	58	65	72	84	90	98	104	100	93	82	67	62	104
	Lowest	-30	-27	-10	-1	17	26	37	31	16	1	-21	-22	-30
Missoula WB AP	Av. Max.	28.8	36.0	43.4	57.0	65.7	71.6	84.5	82.0	71.9	57.7	40.6	32.4	56.0
(19)	Av. Min.	11.7	18.2	23.3	31.8	39.6	45.3	50.0	48.6	41.2	32.6	23.9	17.2	32.0
	Mean	19.2	25.0	33.7	44.3	52.6	58.5	67.0	64.8	55.4	44.0	30.5	23.5	43.2
	Highest	59	60	72	85	92	98	105	98	98	83	65	60	105
	Lowest	-33	-22	-13	14	21	31	36	32	24	16	-23	-21	-33
Butte FAA AP	Av. Max.	27.8	32.7	39.1	50.9	60.7	67.9	80.0	78.0	67.5	56.3	40.3	32.5	52.8
(29)	Av. Min.	1.5	5.5	13.7	25.7	33.5	40.1	45.1	42.5	34.8	26.8	15.0	7.7	24.3
	Mean	15.1	19.5	26.3	38.5	47.3	54.3	62.7	60.3	51.2	41.6	27.7	20.1	38.7
	Highest	54	60	64	79	88	93	100	99	91	83	68	62	100
	Lowest	-48	-52	-36	-13	12	23	29	26	12	-19	-42	-37	-52
Mullan Pass CAA 1/	Av. Max.	23.5	26.7	30.8	41.4	50.8	56.4	68.7	67.0	57.5	45.1	30.9	26.3	43.8
(17)	Av. Min.	13.8	16.5	18.5	27.1	35.0	40.0	49.7	48.4	41.8	32.6	21.8	17.7	30.2
	Mean	18.7	21.6	24.7	34.2	42.9	48.2	59.2	57.7	49.6	38.9	26.4	22.0	37.0
	Highest	44	49	61	75	80	84	92	93	85	76	60	46	93
	Lowest	-24	-20	-17	2	9	26	28	33	21	10	-18	-14	-24
Bonners Ferry	Av. Max.	31.0	37.6	47.6	59.7	68.6	74.3	83.8	81.8	72.3	57.3	41.7	34.5	57.5
(30)	Av. Min.	16.5	20.0	26.3	33.5	40.1	45.9	59.3	47.3	41.7	34.3	26.6	22.3	33.7
	Mean	23.8	28.8	36.9	46.6	54.4	60.1	66.5	64.5	57.0	45.8	34.1	28.4	45.6
	Highest	52	58	71	88	91	96	104	99	97	81	61	56	104
	Lowest	-29	-25	-12	19	17	31	33	28	24	11	-13	-11	-29
Spokane WB AP	Av. Max.	30.0	37.3	45.2	57.0	66.5	73.3	83.7	80.8	73.0	57.7	42.1	34.3	56.7
(13)	Av. Min.	18.1	23.5	28.3	35.3	43.3	49.4	55.4	54.2	47.2	37.5	28.8	24.0	37.1
	Mean	25.3	30.0	38.1	47.3	56.2	61.9	70.5	68.0	60.9	49.1	35.7	30.1	47.8
	Highest	52	61	71	84	92	96	102	98	96	80	61	54	102
	Lowest	-24	-22	-3	21	24	35	40	41	30	20	-11	-9	-24

1/ Period is longer or shorter than the 30-year normal.

Note: The mean temperature is for the normal period 1931-60; other data are for the period of record through 1960. Numbers under station names denote full years of record for all data.

Potential evapotranspiration ranges from 20 to 25 inches in some of the lower elevations in the general Spokane area. Actual evapotranspiration reaches potential levels only in the areas (mostly northern Idaho, northwestern Montana) with adequate precipitation and soil holding capacity. Actual evapotranspiration runs 10 to 12 inches of water in most arable sections, but as much as 2 to 4 inches more on some mountain slopes at the southeastern part of the subregion.

Storms

Most of the precipitable moisture in the air masses is deposited on mountain ranges intervening between the subregion and the ocean. Because of this, storms of high-intensity, short-duration rainfall usually occur over isolated minor areas. The principal storm centers are the upper Spokane River Basin and the Flathead River Basin. In the Flathead at Columbia Falls, 3.77 inches was recorded for June 7, 1924; and in the Spokane the maximum 24-hour precipitation for the December 1933 storm was about 5 inches, with a 5-day total of about 8 inches. The severe Flathead storms are penetrations of continental disturbances through the Rocky Mountains.

Humidity

Humidity variations are similar over the subregion with 75 percent or higher values most mornings throughout the year. But summer afternoon humidity is generally 30 percent or less; sometimes as low as around 10 percent. Oppressive combinations of heat and humidity are seldom experienced even though cold season humidity can remain quite high in the valleys (80-90 percent) for periods of days or weeks.

Sunshine

Cloudiness varies little, with a marked cold season maximum everywhere, and much clear, sunny weather during the warm season. Over the mountains at the southeastern end of the area, scattered thunderstorms develop on 40 to 50 summer afternoons a year. The result is a little more summer afternoon cloudiness in the Butte-Deer Lodge area than in northern Idaho and extreme northeastern Washington.

SURFACE WATER

The rivers of the Clark Fork-Kootenai-Spokane Subregion are extensively used, the water supply is moderate and late in the

year, and the quality is mostly excellent. The upper Clark Fork River Basin lies in the precipitation shadow of the Bitterroot Range and is an area of low runoff. The runoff is primarily from spring snowmelt, with varying amounts of rainfall included. Flood flows are highly regulated, not only by large natural lakes but also by Hungry Horse Reservoir on the South Fork Flathead River and power dams at the lakes and elsewhere. A large block of flood control storage will be provided by the new Libby Reservoir on Kootenai River.

Water is used for power generation at the outlets of Flathead, Pend Oreille and Coeur d'Alene Lakes and Hungry Horse Reservoir and at 10 other reservoirs with capacity of at least 5,000 acre-feet. Also, power will be generated at Libby Dam.

The largest areas under irrigation are in the Clark Fork above St. Regis, in the Flathead, and in the Spokane River Basins. There are 14 reservoirs in the subregion with capacities of more than 5,000 acre-feet each that are used primarily for irrigation. In addition, Hungry Horse Reservoir and Flathead Lake serve irrigation by regulating and maintaining adequate downstream flows.

Quantity

Average discharge of streams originating in the subregion totals about 36,253 cfs (26.2 million acre-feet annually). This averages 1.0 cfs per square mile, which is an intermediate rate. An additional 12,305 cfs flows into the subregion from Canada.

Present Utilization

About 7.2 percent of the average discharge was withdrawn in 1965 for consumptive uses, but only about 2.7 percent was actually consumed. About 8 percent of the water withdrawn for consumptive uses (about 2,600 cfs) is for municipal supplies (157 cfs domestic and 46 cfs industrial). This is the second largest user; the largest user is irrigation (2,200 cfs). Irrigation is also the largest consumer, 884 cfs of the total of 968 cfs consumed in the subregion. Very little steam power is generated in the subregion and then mainly during the winter months. A large quantity of water is used to generate hydroelectric power. Recreation is popular, and all waters are being used for fish and wildlife. Sport fishing is nationally famous. Pollution is a problem only in the upper Clark Fork River and on South Fork Coeur d'Alene River, due to mining operations.

Stream Management

Competition for water among the various users necessitates efficient stream management. Storage and release, diversions, conservation, legal constraints, etc., all are a part of the water-management system.

Impoundments Reservoirs having a total capacity of 5,000 acre-feet or more are listed in table 19. Libby Dam, now under construction, will form the largest reservoir in the subregion; however, Hungry Horse Reservoir on the South Fork Flathead River is the largest existing impoundment. Flathead and Pend Oreille Lakes have over a million acre-feet of active storage capacity apiece. The table lists 32 reservoirs, 12 designed to serve two purposes and three designed to serve four or five purposes.

Releases from flood control and power reservoirs where snowmelt is the primary cause of runoff generally follow a pattern of withdrawal during the fall and winter and refill during the spring. The reservoirs are full for 1 to 5 months beginning with June or July.

The impoundments have variable short-term effects on river discharge. The changes in discharge due to power loads are abrupt, and, on weekends when less power is required, flows may be low. Municipal water is supplied during the summer, principally to satisfy lawn-watering and air-conditioning needs. Irrigation water is supplied at a fairly constant rate from April through September. On the other hand, recreation use requires that the water be retained in the reservoirs as long as possible during the summer.

Diversions Most of the diversions in the Clark Fork-Kootenai-Spokane Subregion are for irrigation. Other diversions are made for municipal, industrial, and drainage uses. Although there are many diversions, the quantity of water involved is small. The largest diversions are in the Flathead and Spokane river basins.

Channel Modification Channel modification and diking have been performed in many reaches such as on the Kootenai River in the vicinity of Bonners Ferry and the upper Flathead River. In addition, some stream improvement work has been accomplished on many of the smaller tributaries.

Forecasting Forecasting is used in flood control operations of reservoirs, flood warning, and to provide a maximum of stored water for power generation, municipal use, and irrigation, consistent with assured refill of the reservoirs. The U.S.D.C. Weather Bureau is officially responsible for providing a flood-warning service to the general public at times of major flooding.

Table 19 - Reservoirs Having a Total Capacity of 5,000 Acre-feet or More, Subregion 1

Name	Stream	Total Storage (acre-feet)	Active Storage (acre-feet)	Surface Area (acres)	Purpose[1/]
Ashley Lake	Ashley Cr.	20,000	20,000	3,000	I
Boundary	Pend Oreille R.	94,600	43,000	-	MP
Box Canyon	Pend Oreille R.	6,900	-	-	P
Cabinet Gorge	Clark Fork R.	112,000	42,800	3,230	P
Calispell Lake	Calispell Cr.	10,000	-	-	P
Coeur d'Alene Lake	Spokane R.	238,500	225,000	32,000	P
Como Lake	Rock Cr.	36,690	34,800	940	I
E. F. Rock Creek	E. F. Rock Cr.	-	16,000	440	I
Flathead Lake	Flathead R.	1,791,000	1,219,000	126,000	FIPR
Georgetown Lake	Flint Cr.	31,040	31,000	3,000	PW
Hubbart	L. Bitterroot R.	12,100	12,100	460	IR
Hungry Horse	S. F. Flathead R.	3,468,000	2,982,000	23,800	FIPRN
Kicking Horse	Crow Cr.	-	8,400	785	I
L. Bitterroot Lake	L. Bitterroot R.	26,000	26,000	2,900	I
Lake Spokane (Long Lake)	Spokane R.	252,800	104,200	5,000	P
Libby	Kootenai R.	5,850,000	4,965,000	46,500	FPR
Lower Crow	Crow Cr.	-	10,350	340	I
Lower Jocko Lake	M. F. Jocko R.	7,580	6,400	116	IR
Lower Willow Creek	Willow Cr.	5,100	-	-	I
McDonald	Post Cr.	10,600	8,200	200	I
Mission	Mission Cr.	-	7,250	290	I
Nevada Creek	Nevada Cr.	-	12,640	375	I
Ninepipe	Flathead R.	14,870	14,870	1,600	CI
Noxon Rapids	Clark Fork	495,600	334,600	7,900	P
Pablo	Flathead R.	29,600	27,100	2,040	I
Pend Oreille Lake	Pend Oreille R.	1,561,300	1,155,100	94,600	CFNPR
Priest Lake	Priest R.	215,000	72,400	23,400	PR
Sullivan Lake	Harvey Cr.	-	31,000	1,290	P
Tabor	Dry Cr.	-	23,300	285	I
Thompson Falls	Clark Fork	69,400	14,970	1,450	P
Painted Rocks Lake	W. F. Bitterroot R.	32,360	31,700	655	R

1/ C-fish & wildlife conservation, F-flood control, I-irrigation, M-municipal, N-navigation, P-power, R-recreation, W-industrial.

Forecasts of seasonal quantities of water available for storage are made using snow-survey data, precipitation data, data on antecedent conditions, and other parameters. The information is processed by digital computer and updated each month as new data are obtained.

Water Rights

Montana A water right in Montana is a right by appropriation and is limited to the beneficial use of water. Right by appropriation was enacted by the prevailing law of a mining economy and was patterned after rules applied to mining claims - first in time is first in right. The earliest water right in Montana was recorded in 1852, an appropriation in Ravalli County from Burnt Fork Creek, a tributary of the Bitterroot River.

Water users are not required to file official records of the completions of their appropriations, so the actual amount of use may be different from the amount appropriated; on unadjudicated streams, appropriations almost always are greater than amounts actually used and distribution of water is neither regulated nor supervised.

Water can be appropriated for the beneficial use of people and municipalities, agriculture, industry, power generation, recreation, and the rehabilitation of forest areas. The amount of water appropriated for irrigation is considerably more than the combined total amount appropriated for all other categories.

In order to "appropriate, conserve, store, distribute, and utilize the water resources of the State of Montana," the State Water Conservation Board (now the Water Resources Board) was created in 1933 and empowered to initiate and construct projects for impounding and conserving water including but not restricted to "flood, waste, and surplus water."

Water appropriations of record in the Kootenai Basin total approximately 150,000 cfs. Only one-quarter of this is attributed to non-irrigation appropriations. Most of the irrigated land is concentrated in the northeastern part of Lincoln County, where lake storage is used to augment streamflow. At present, there appears to be adequate water for irrigation but as new irrigable land is put into production, shortages will develop.

The total appropriations in the Clark Fork Basin are approximately 3,100,000 cfs which far exceed the available flow. Three-fourths of this is appropriated from the Flathead River subbasin in Lake County. Ninety-six percent of the appropriations in Lake County are from the lower Flathead River below Flathead Lake. The natural flow of the river is regulated by lake and reservoir storage. The major appropriator in Lake County is the United States of America with multiple duplicate filings to irrigate some 100,000 acres of the Flathead Irrigation Project.

Appropriations in the Clark Fork subbasin total approximately 775,000 cfs. This includes appropriations of record from the drainages of the Upper Clark Fork, the Blackfoot, and the Bitterroot Rivers. At the height of the irrigation season, acute water shortages occur in the Bitterroot Valley in Ravalli County and in the Upper Clark Fork Valley in Deer Lodge and Powell Counties.

The valley of the Bitterroot and its tributaries is the only drainage basin in Ravalli County. Including the West Fork, the Bitterroot runs south-to-north the full length of the County. There are 104,000 acres of land in the County which depend on water of the Bitterroot and tributaries for irrigation. Tributaries flow out of the mountains into the Bitterroot, but the path of flow is short and topographic relief is sharp. Hence, dams on these tributaries impound relatively small reservoirs. A few lakes in the Bitterroot Mountains augment storage, but classification of the Selway-Bitterroot Wilderness in 1963 prevents further development in most of this area.

The Upper Clark Fork flows through one of the more populated parts of Montana, from the vicinity of the city of Butte, past Anaconda to Deer Lodge, a distance of less than 50 miles. Outside of the metropolitan areas are 76,000 acres in Deer Lodge and Powell Counties requiring water for irrigation. Industry, too, requires, a substantial amount of surface water. The major seasonal shortage occurs in the valley between the cities of Anaconda and Deer Lodge.

Much adjudication has taken place in Montana's portion of the Columbia Basin. However, the total amount of water used can only be estimated. Non-irrigation categories probably consume less than 100,000 acre-feet (137 cfs) of water annually, although appropriations are much greater. Appropriations of record for power generation at present total approximately 83,500 cfs. Industrial appropriations for mining and milling and for paper and pulp manufacturing are significant. Shortages occur during the irrigation season because storage facilities are not adequate.

Idaho Only in a few cases have the rights to the use of water from the Columbia River tributaries in northern Idaho been determined by court action. These are mainly for mining and manufacturing purposes with small amounts for other purposes. Permits have been issued for many uses including power and for irrigation of small areas, particularly on the Rathdrum Prairie. In addition to these, licenses are held by the Governor to preserve Priest, Coeur d'Alene, and Pend Oreille Lakes for use by the public. The constitutionality of such appropriation has not been demonstrated.

There is unappropriated water on most streams in northern Idaho. The exceptions to this are the smaller streams and lakes where there are presently extensive uses for mining or industrial purposes. Future development will likely increase the conflicts between groups using water for some consumptive use and those wishing to preserve the lakes and streams for their recreation value. Such conflicts already exist in several locations in this part of Idaho.

Washington In that part of the Clark Fork-Kootenai-Spokane Subregion located in the State of Washington, essentially Water Resource Inventory Areas 54 through 57 and 62 (figure 27), a total of 589 active surface water right appropriation records, in permit and certificate stages, were on file with the Department of Water Resources on April 30, 1967. Prime rights in this area allow summer period diversions totaling 70,182.59 cfs of which consumptive diversions amount to 290.37 cfs, partially consumptive diversions are permitted for 29,987.85 cfs, and nonconsumptive diversions total 39,904.37 cfs. Under supplemental rights a total of 11.36 cfs has been appropriated.

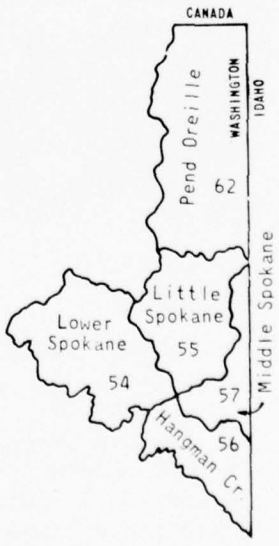


Figure 27 Map showing water resource inventory areas defined by the State of Washington Department of Water Resources.

Adjudication decrees in this portion of the subregion provide for a total of 39 rights with prime right diversion quantities amounting to 2.69 cfs; 2.49 cfs being consumptive and 0.20 cfs being nonconsumptive to the resource. Supplemental adjudicated rights have been granted for a total of 0.40 cfs.

Reservoir storage rights perfected under the appropriative system provide for the annual retention of 137,545 acre-feet of water in the State of Washington segment of this subregion.

Prime water right quantities for the more important use categories and total actual surface water right quantities are listed in table 20 according to Water Resource Inventory Areas as defined by the State of Washington, Department of Water Resources. More detailed information about specific rights can be obtained from the Department of Water Resources.

Table 20 - Surface Water Rights in the Clark Fork-Kootenai-Spokane Subregion, 1967

Appropriative Rights

Basin No.[1]	River Basin	Municipal	Irrigation	Indiv. & Comm. Domestic	Indus. & Comm.	Fish Propagation	Stock	Total[2]	Reservoir Storage Rights in Acre-Feet
54	Lower Spokane	--	15.89	0.39	--	10.10	0.16	2,327.19[3]	--
55	Little Spokane	--	49.05	5.11	20.05	44.16	2.36	115.39	2,972
56	Hangman Creek	--	15.82	0.12	--	1.49	0.26	17.69	--
57	Middle Spokane	--	10.22	0.30	44.00	0.40	0.05	3,054.77[5]	74
62	Pend Oreille	1.67	93.86	85.92	25.40	8.10	4.72	64,667.55[6]	134,499[7]
Appropriative Totals		1.67	184.84	91.84	89.45	64.25	7.55	70,182.59	137,545
Adjudicated Rights									
55	Little Spokane	--	1.20[4]	1.22[4]	--	0.20	1.22[4]	1.42	--
56	Hangman Creek	--	0.21	0.01	--	--	--	0.21	--
62	Pend Oreille	--	1.00	0.46	--	0.40	0.06	1.06	--
Adjudicated Totals		--	2.41	1.69	--	0.60	1.28	2.69	--
Combined Totals (Approp. & Adjud.)		1.67	187.25	93.53	89.45	64.85	8.83	70,185.28	137,545

1/ Water Resource Inventory Area number as shown in figure 27.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed and (2) water right quantities that are common to two or more uses are listed under each applicable use category.
3/ Includes 2,300.00 cfs for hydroelectric power generation.
4/ Nearly all the quantities for irrigation, individual & community domestic supply & stock are common.
5/ Includes 3,000.00 cfs for hydroelectric power generation.
6/ Includes 64,501.00 cfs for hydroelectric power generation.
7/ Includes 29,704 acre-feet for Box Canyon Pool and 94,500 acre-feet for Boundary Pool.

Discharge

The base period selected for the Columbia-North Pacific Region study is the 30-year interval 1929-58. A typical Subregion 1 stream, Kootenai River at Libby, Montana, shows a base-period mean discharge equal to 98 percent of its long-term mean (55 years, 1911-1965). Weather records show that precipitation near Libby during the base period was 94 percent of the long-term mean (70 years, 1896-1965.) Thus, the selected base period provides reasonably average data for statistical analysis.

Table 21 - Streamflow Summary for Selected Sites, Subregion 1

Stream	Station	Station Number	Gage Datum (ft.)	Drainage Area (sq.mi.)	Period of Record	Annual Flows (cfs) 1/ Mean	Max.	Min.	Momentary Flow (cfs) 2/ Max.	Min.
Kootenay River	Newgate, B. C.	3000	2,310.23	7,660	31-65	9,993	14,222	6,079	98,200	994
Kootenai River	Libby	3030	2,041.54	10,240	10-65	11,473	16,134	7,978	121,000	895
Kootenai River	Leonia	3050	1,700.25	11,740	28-65	13,277	18,950	9,174	123,000	996
Moyie River	Eileen	3075	2,124.50	755	26-65	854	1,322	323	11,000	40
Kootenai River	Porthill	3220	1,700.00	13,700	28-65	15,328	22,143	9,921	125,000	1,380
Blackfoot River	Bonner	3400	3,344.76	2,290	40-65	1,479	2,207	555	19,200	200
Clark Fork	Missoula	3405	3,230.00	5,999	29-65	2,761	4,708	1,335	31,700	115
Clark Fork	Missoula	3530	3,090.00	9,003	29-65	5,066	8,350	2,565	52,800	388
Flathead River	Flathead, B.C.	3550	3,970.00	450	30-65	863	1,297	419	16,300	65
Flathead River	Columbia Falls	3555	3,145.59	1,548	29-65	2,894	4,146	1,383	69,100	198
S.F. Flathead River	Columbia Falls	3625	3,040.00	1,663	28-65	3,342	4,579	1,551	46,200	7.3
Flathead River	Columbia Falls	3630	2,977.67	4,464	28-65	9,552	14,104	5,788	176,000	798
Flathead River	Polson	3720	2,693.70	7,096	07-65	10,906	15,744	6,366	82,800	5
Clark Fork	Plains	3890	2,449.34	19,958	10-65	18,328	26,253	9,954	134,000	3,200
Clark Fork	Whitehorse Rapids	3920	2,060.00	22,067	28-65	20,889	30,086	11,266	153,000	270
Pend Oreille River	Newport	3955	2,000.00	24,200	03-41,52-65	24,457	35,269	14,408	136,000	1,280
Pend Oreille River	Z Canyon	3985	1,721.18	25,200	12-64	25,839	37,624	14,861	171,300	2,500
Coeur d'Alene River	Cataldo	4135	2,100.00	1,200	20-65	2,471	3,862	1,043	67,000	122
Spokane River	Spokane	4225	1,696.60	4,290	91-65	6,485	10,353	2,970	49,000	95

1/ Regulated values for base period (1929-1958) with estimated 1970 conditions of development.
2/ Maximum and minimum observed instantaneous values for period of record.

Measurement Facilities Measurement facilities comprise primarily the gaging stations and their characteristics where the measurements are made. Table 21 summarizes pertinent streamflow data for the 19 sites selected for detailed study in Subregion 1.

Figure 29 shows the locations of the selected sites, with U.S.D.I. Geological Survey identification numbers. The first two digits of the identification number, part number (12), have been omitted because Subregion 1 lies wholly within the area designated as Part 12, Pacific slope basins in Washington and upper Columbia River Basin.

Average Discharge for Subregion 1 Figure 28 presents monthly discharge data for the subregion as a whole. The discharge is the sum of inflows from Canada and flows generated within the subregion. It gradually reaches a maximum in May and June from spring snowmelt and recedes to a minimum in September. The within-area generated flows are also shown in table 22. Isopleths showing mean annual runoff for the period 1931-60 are shown on figure 29.

Average Discharge for Selected Stations In this section of the report, detailed data are presented for each of the selected sites listed in table 21. (tables 23 to 41)

The monthly discharges presented for the four river stations Moyie at Eileen, Flathead at Flathead, Flathead near Columbia Falls, and Coeur d'Alene near Cataldo are available in Geological Survey Water-Supply Papers 1316 and 1736, compilations of surface-water records in Part 12. For the remaining stations an assumed plan of

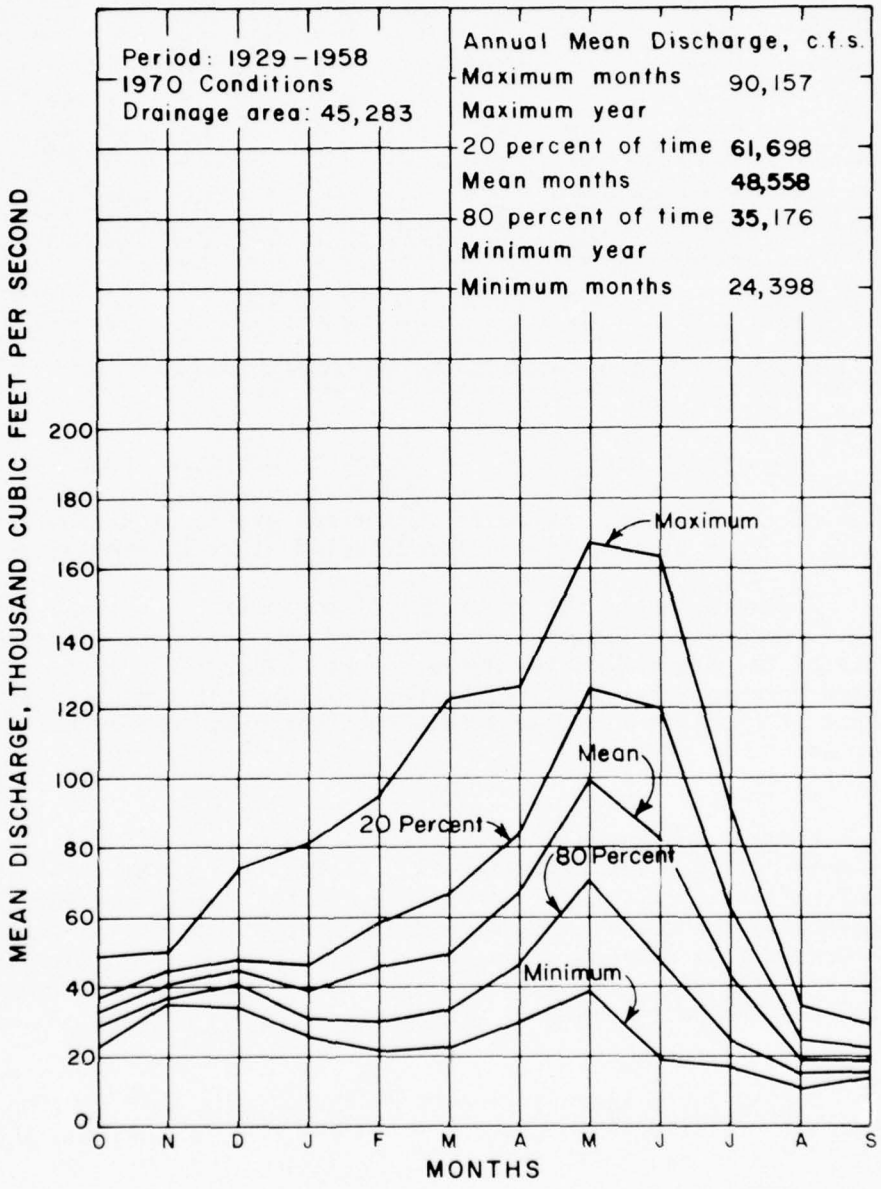
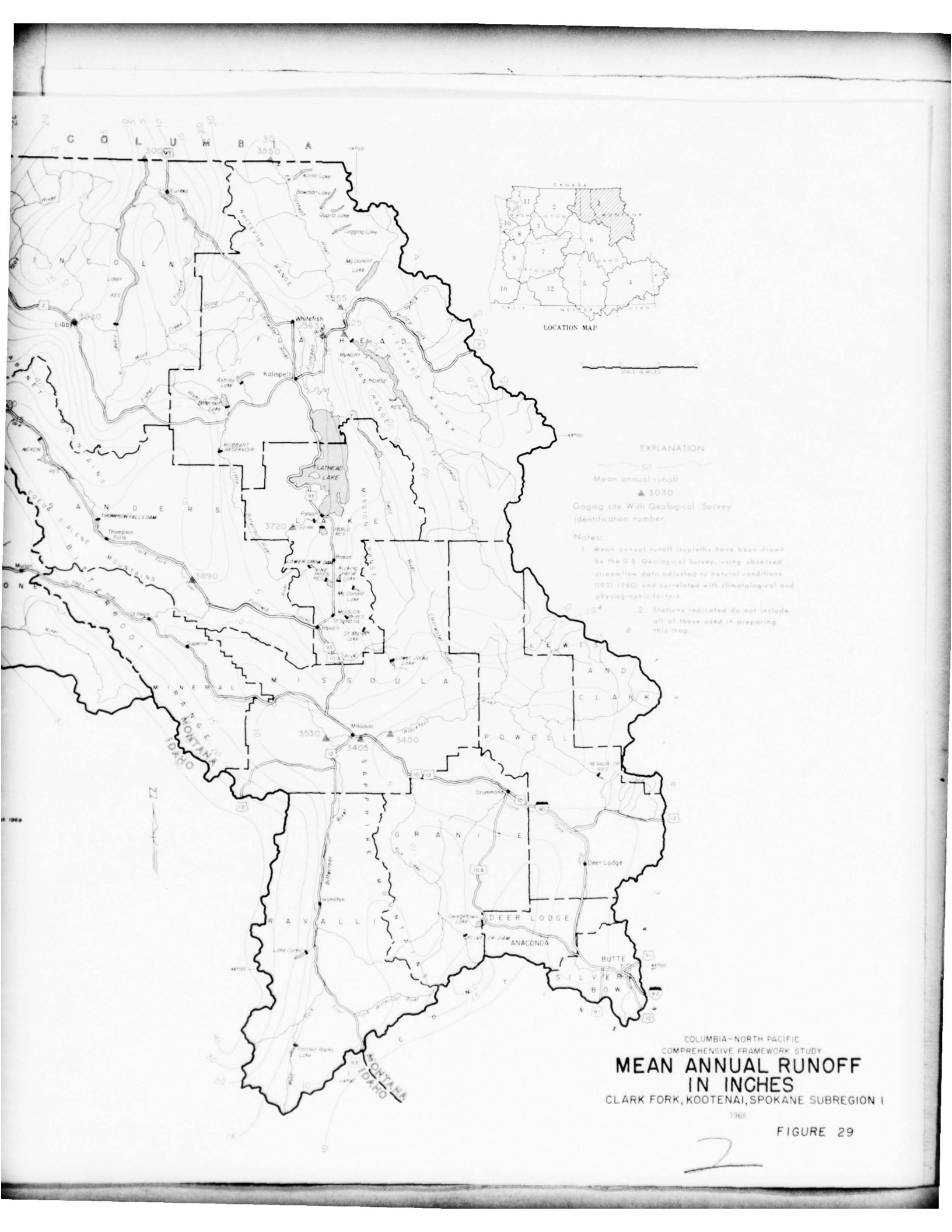


Figure 28. Monthly discharge, from Subregion I.


B R I T I S H C O L U M B I A
BOUNDARY
PEND OREILLE
BONNER
KOOTENAI
SHOSHONE
BENEWAH
STEVENS
LINCOLN
SPOKANE
LIBERTY LAKE
LINCOLN
FLATHEAD
SANDERS
MINERAL
MISSOULA
RAVALLI
Boundary
Priest River
Sandpoint
Newport
Colville
Deer Park
Chattaroy
Spokane
Coeur d'Alene
Post Falls
Kellogg
Wallace
Mullan
St Maries
Libby
Kalispell
Whitefish
Thompson Falls
Hamilton
Missouri
Bonner
Priest Lake
Pend Oreille Lake
Lake Coeur d'Alene
St Joe River
St Regis River
Clark Fork River
Flathead Lake
Flathead River
Swan Range
Cabinet Mountains
Coeur d'Alene Mountains
Bitterroot Mountains
Mission Range
Salish Mountains
Whitefish Range
Purcell Mountains
Long Lake
Albeni Falls Dam
Box Canyon Dam
Cabinet Gorge Dam
Noxon Rapids Dam
Thompson Falls Dam
Hubbart Reservoir
Libby Dam
Kerr Dam
Hungry Horse Dam
Bonner Ferry
Sinners Ferry
WASHINGTON
IDAHO
MONTANA
Base Rev. Oct. 1969



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES

CLARK FORK, KOOTENAI, SPOKANE SUBREGION 1

1968

FIGURE 29

2

Table 22 - Modified Discharge in Clark Fork-Kootenai-Spokane Subregion, 1929-58

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Mean
						(Mean Discharge, in cfs)							
						Maximum							
Total	48,380	49,785	74,818	81,027	94,733	122,738	125,606	167,592	163,425	90,130	34,823	28,828	90,157
Canada	12,008	5,596	7,164	6,292	4,934	5,863	26,276	56,601	60,454	41,601	12,668	4,835	20,358
Subregion	36,372	44,189	67,654	74,735	89,799	116,875	99,330	110,991	102,971	48,529	22,155	23,993	69,799
						20 Percent							
Total	37,052	44,245	47,842	46,346	58,154	66,494	83,388	125,801	120,004	62,851	25,281	22,912	61,698
Canada	5,749	6,048	3,905	3,342	3,323	3,305	9,997	38,070	56,852	31,296	10,171	7,580	14,970
Subregion	31,303	38,197	43,937	43,004	54,831	63,189	73,391	87,731	63,152	31,555	15,110	15,332	46,728
						Mean							
Total	32,859	40,842	44,864	39,219	45,574	48,746	67,478	99,825	81,717	42,462	19,745	19,367	48,558
Canada	5,993	4,930	3,794	3,126	3,034	3,381	10,922	36,283	40,266	20,624	8,843	6,463	12,305
Subregion	26,866	35,912	41,070	36,093	42,540	45,365	56,556	63,542	41,451	21,838	10,902	12,904	36,253
						80 Percent							
Total	28,885	36,997	40,392	31,682	30,070	33,401	46,239	70,381	47,699	25,176	15,573	15,619	35,176
Canada	4,763	3,300	2,837	1,914	2,681	3,561	5,670	28,269	30,134	14,214	7,733	5,218	9,191
Subregion	24,122	33,697	37,555	29,768	27,389	29,840	40,569	42,112	17,565	10,962	7,840	10,401	25,985
						Minimum							
Total	23,146	35,698	34,214	26,293	21,697	22,559	29,780	38,775	19,144	16,978	10,545	13,941	24,398
Canada	4,919	5,052	2,620	2,614	2,224	2,324	8,354	21,601	19,144	11,416	7,250	5,902	7,785
Subregion	18,227	30,646	31,594	23,679	19,473	20,235	21,426	17,174		5,562	3,295	8,039	16,613

Note: 1. Subregion discharge is that which originates in the subregion.
2. Twenty percent and 80 percent represent the discharge available 20 and 80 percent of the tim

reservoir regulation has provided adjusted flows through a computer program. Records for several of the sites have been extended by correlation with nearby stations. Since these remaining sites required changes in their recorded flows, the values shown in the tables have been termed modified mean discharge; the values for the four tables 26, 31, 32, and 40 have been termed observed mean discharge.

Hydrographs for several conditions of flow at the selected sites are shown on figures 30 to 48. It should be noted that the supply of water indicated by these monthly discharge hydrographs is not necessarily available for development, even though it already reflects depletions and storage regulation. Water may have been committed to downstream use such as irrigation. Explanations of the hydrographs and the succeeding graphs are in the regional summary. It will be noted that the peaks occur in May or June for the upper Kootenai and Clark Fork Rivers, but in February and March in the lower Kootenai. The South Fork Flathead River peaks in April, while the Spokane River has two peaks, December-January and April-May. The Kootenai River has the relatively highest base flow, although its tributary, the Moyie River, has a very low base flow.

Frequency curves of annual high and low discharges are shown on figures 49 to 67. The slopes of the curves from one stream to another are fairly uniform, with high flows being greatest for the Clark Fork River but least for the Flathead River; and with low flows being greatest for the Flathead and Moyie Rivers but least for the Spokane and upper Kootenai Rivers. The spread of the curves from 1-month to 12-month flows is quite variable. The greatest

spread for high flows is shown for the Moyie and Coeur d'Alene Rivers, being low for the Kootenai River. For low flows the spread is greatest for the Moyie, Coeur d'Alene, and South Fork Flathead Rivers and least for the Kootenai and Clark Fork Rivers.

Duration curves for three flood conditions, daily, monthly, and annual, are presented in figures 68 to 86. The monthly and annual discharges used are those of tables 23 to 41, but the daily flows are observed for the period of record wherever they are provided in the Geological Survey daily summaries. The Spokane River has the greatest slope of annual duration curve, and the Moyie and Flathead Rivers have the greatest departure of monthly from annual curve.

Frequency curves of annual peak flows are shown in figures 87 to 105. Curves for both regulated and unregulated conditions are presented where flows are modified by reservoirs; this includes six stations on the Flathead and Clark Fork Rivers affected by Hungry Horse Reservoir. The curves with greatest slope are for the Coeur d'Alene and upper Clark Fork Rivers. All curves exhibit negative skew, or upward convexity, which is characteristic of these snowmelt streams.

Dependable yields of the streams in the subregion are given in tables 42 to 60. Each table shows the lowest mean flows for from 1 to 10 consecutive years in the 30-year base period and their relationship to the 30-year mean. The difference between any two flows is a measure of the additional reservoir storage capacity required to make the higher flow available; the Coeur d'Alene, Moyie, and upper Clark Fork Rivers would require relatively more storage. The Blackfoot River near Bonner, Montana, has a minimum-year flow of only 37 percent of the 30-year mean (table 47). On the other hand, the minimum-year flow of Kootenai River at Libby is 70 percent of the 30-year mean (table 43). The average minimum-year discharge for all streams is about 53 percent of the mean.

Variations in Discharge Long-term variations in discharge and precipitation are presented for three streams in figures 106, 107, and 108. The annual means for the base period and for the entire period of record are shown. Although the annual precipitation for a single year varied from the mean by as much as 66 percent, the 5-year moving average varied from the mean by no more than 37 percent.

The 5-year moving averages are presented in order to indicate trends more clearly. Although records are shorter for this subregion, the same general trend is revealed as for the other subregions; namely, a general decline in precipitation from as far back at least as the beginning of the century to 1945, with recovery since them.

As indicated in the discussions on frequency and duration curves, the variation in annual flows at selected sites during the 30-year base period is fairly uniform from stream to stream. The higher slopes for the Clark Fork River indicate the greater annual variability for this river, as well as for the Moyie River. The maximum annual discharge is generally about 2.9 times the minimum annual discharge, ranging from 2.0 for the Kootenai River to 4.1 for the Moyie River and 3.9 for the Upper Clark Fork. The greatest annual peak variability is exhibited by the upper Clark Fork and the Coeur d'Alene Rivers.

Seasonal variations in runoff are clearly shown in the hydrographs of figures 30 to 48. The usual short period of high runoff for the snowmelt period is lengthened greatly by the addition of an early rain-runoff period in the Spokane and lower Kootenai Rivers; this is reflected in the shape of the duration curves.

The wide spread in both the high- and low-flow frequency curves for the Moyie and Coeur d'Alene Rivers indicates great variation from monthly to annual mean discharge; this is confirmed by the departure of the monthly from annual duration curve for these streams. The low runoff occurs in August and September for all streams in the subregion, and is extended for a period as long as 7 months for some high-elevation streams such as the Flathead River at Flathead, B. C. Streams with deep snowpacks, such as the Kootenai River, have the smallest variations in seasonal flows.

Streamflow Travel Time No time-of-travel studies have been made in Subregion 1. However, some approximate flood wave travel times in minutes per mile have been determined from flood routing studies as follows:

From	To	High Flow Rate
Libby Dam	Mouth Kootenai River	6
Hungry Horse Dam	Pend Oreille Lake	9
Pend Oreille Lake	Mouth Pend Oreille River	11

To these times must be added the time of passage through the lakes when they are under free-flow conditions: about 9 days for Kootenay, 9 days for Flathead, 6 days for Pend Oreille, and 5 days for Coeur d'Alene Lake.

River Profiles Representative river profiles are presented on figures 109 through 111. The profiles were prepared using topographic maps and the River Mile Index reports prepared by the Columbia Basin Inter-Agency Committee.

(Narrative continued on page 190)

Table 23 - Modified Mean Discharge in c.f.s., Kootenay River at Newgate, British Columbia

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										23,274	8,252	5,095	
1929	5,466	3,218	2,262	2,126	2,252	2,250	2,545	17,286	34,284	12,860	6,921	4,741	8,030
1930	3,335	2,205	2,170	2,091	2,431	2,230	8,504	17,200	31,805	17,027	7,703	5,195	8,530
1931	3,772	2,797	2,185	2,026	1,922	2,027	2,928	16,493	20,431	9,520	5,128	4,476	6,160
1932	3,122	2,517	2,365	1,856	2,452	3,297	6,618	27,393	43,631	16,140	7,868	5,446	10,221
1933	4,292	4,157	2,595	2,666	2,242	2,397	5,958	22,293	49,231	24,940	10,178	7,686	11,572
1934	8,302	7,45[illegible]	5,385	4,546	3,602	4,387	24,148	41,293	28,231	13,040	6,628	4,616	12,672
1935	3,572	4,297	2,815	2,666	3,212	2,737	4,648	20,993	37,231	22,940	9,368	5,366	10,011
1936	3,692	2,837	2,335	2,046	1,592	2,247	8,708	26,493	21,731	8,970	5,248	4,016	7,505
1937	2,982	2,177	1,975	1,626	1,752	1,797	3,058	18,193	26,131	13,540	6,708	4,626	7,069
1938	4,332	5,137	2,965	2,816	2,322	2,757	9,418	30,793	41,431	17,440	6,348	5,056	10,924
1939	4,192	3,087	2,395	2,546	1,922	2,807	8,238	24,193	22,031	16,440	6,218	4,696	8,268
1940	5,342	4,697	3,605	2,396	2,422	2,877	7,308	25,793	21,931	9,640	5,558	5,716	8,118
1941	5,152	3,417	2,795	2,366	2,172	3,147	7,978	16,593	17,231	8,610	5,358	7,946	6,911
1942	7,512	5,127	5,815	3,186	2,612	2,487	8,138	27,493	35,631	27,540	11,178	7,046	12,035
1943	5,312	3,947	3,125	2,436	2,682	2,637	15,948	19,493	30,731	28,240	9,488	5,366	10,815
1944	4,492	3,297	2,345	2,146	2,022	1,997	3,628	15,093	19,631	7,960	5,548	4,756	6,079
1945	4,232	2,937	2,025	1,926	1,912	1,937	2,588	17,593	30,331	16,440	6,518	5,686	7,865
1946	4,402	3,827	2,675	2,286	2,122	2,727	9,058	35,093	38,731	20,140	8,588	[illegible],536	11,472
1947	5,312	3,497	2,805	1,946	2,562	3,267	8,998	36,593	32,931	17,240	7,898	6,8[illegible]	10,865
1948	11,702	7,317	4,265	2,956	2,572	2,697	7,058	39,993	50,831	17,440	10,678	6,056	13,645
1949	4,692	3,657	2,425	2,436	2,572	2,867	7,498	28,093	20,831	9,740	6,358	4,926	8,039
1950	4,142	4,007	3,285	2,426	2,292	2,707	5,098	20,293	46,431	27,940	10,378	6,256	11,299
1951	6,752	6,017	5,365	3,856	4,762	3,447	9,768	39,893	36,431	32,840	11,478	9,286	14,222
1952	8,692	5,637	3,895	3,686	3,162	2,847	11,348	27,093	28,931	17,840	8,468	5,896	10,640
1953	4,212	2,937	2,535	2,986	2,782	2,487	4,338	19,893	42,431	24,740	9,628	5,786	10,421
1954	4,622	4,007	2,975	2,496	2,802	2,667	4,178	33,493	46,231	39,840	14,378	9,626	14,012
1955	5,882	5,117	3695	2,766	2,532	2,427	3,558	14,693	46,131	27,240	10,078	6,086	10,871
1956	6,742	5,837	3,665	3,096	2,542	3,117	9,878	41,293	49,831	23,240	9,078	5,656	13,680
1957	5,062	3,807	2,865	2,236	2,362	2,627	4,348	36,893	29,531	11,940	6,528	4,586	9,444
1958	4,092	3,317	2,585	2,216	2,362	2,507	4,548	34,493	27,631	14,240	6,668	5,446	9,220
Mean	5,180	4,076	3,073	2,562	2,498	2,680	7,334	26,416	33,619	18,524	8,072	5,880	9,993

Table 24 - Modified Mean Discharge in c.f.s., Kootenai River at Libby, Montana

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										23,590	8,169	5,575	
1929	6,485	9,173	12,725	15,179	10,298	9,710	4,740	16,931	4,136	7,937	6,771	5,197	9,133
1930	3,869	10,031	15,071	15,816	12,886	11,601	7,331	16,229	3,986	7,344	7,587	5,687	9,794
1931	9,126	14,802	6,186	16,012	14,311	13,330	4,347	5,114	6,924	10,025	4,976	10,130	9,574
1932	12,091	12,571	14,609	13,703	8,896	9,919	5,166	7,636	6,468	5,173	7,921	6,150	9,236
1933	4,834	10,542	13,339	15,317	29,821	28,366	6,399	27,779	6,794	3,510	3,828	8,453	13,169
1934	9,381	11,374	8,492	7,483	46,004	44,220	17,601	8,778	6,642	13,460	6,682	5,261	15,254
1935	4,265	11,102	13,341	8,667	25,333	22,999	6,303	26,372	6,191	3,460	5,237	5,910	11,532
1936	4,205	9,535	14,123	10,772	8,948	10,038	6,725	7,745	14,903	8,839	4,892	4,358	8,755
1937	3,334	9,405	14,405	15,363	17,454	7,895	6,357	5,071	3,743	3,295	5,654	6,310	8,133
1938	10,127	8,893	11,091	15,995	23,021	22,139	7,404	8,082	10,200	17,068	6,202	5,527	12,102
1939	4,765	9,631	12,786	14,336	9,394	10,062	7,130	28,529	3,536	3,336	4,095	5,127	9,427
1940	5,794	11,463	13,576	12.820	9,500	10,085	4,892	23,940	3,542	3,207	3,133	6,045	9,029
1941	5,617	10,498	13,485	13,850	9,120	9,740	4,844	8,272	7,596	5,924	6,417	7,117	8,546
1942	4,152	7,241	13,800	15,662	27,831	25,638	6,947	31,958	4,112	3,081	3,236	5,991	12,415
1943	5,755	10,277	13,044	15,626	25,973	24,587	13,751	20,154	5,971	3,547	6,441	5,988	12,522
1944	5,123	9,569	12,723	14,957	10,328	10,017	4,551	13,853	3,431	3,505	5,939	9,381	8,626
1945	10,312	12,266	12,047	10,143	10,813	10,206	9,744	4,893	5,920	3,340	3,149	3,154	7,978
1946	9,665	9,984	3,284	16,184	22,799	22,382	7,315	8,454	6,279	18,883	8,563	8,163	11,782
1947	6,023	9,324	8,302	11,843	28,548	28,267	8,492	8,622	6,942	17,648	7,847	7,450	12,358
1948	13,533	10,423	11,843	15,275	35,327	33,509	12,100	15,056	7,383	18,274	11,244	6,872	15,870
1949	5,376	9,438	12,581	15,429	9,735	9,935	7,705	8,091	15,995	9,939	6,360	5,493	9,673
1950	4,668	10,369	13,644	15,631	29,584	28,917	6,201	26,108	6,734	3,560	5,590	6,624	13,063
1951	7,731	9,807	8,074	12,717	43,451	38,593	15,090	14,457	6,162	17,205	11,780	10,438	16,134
1952	11,633	11,242	12,909	13,341	25,293	23,388	9,572	7,937	5,879	17,214	8,417	6,306	12,742
1953	4,697	9,625	14,072	14,339	23,294	21,111	6,322	24,769	6,425	3,482	6,399	6,361	11,696
1954	5,215	9,889	13,402	15,577	32,261	30,143	8,266	20,061	6,650	24,184	14,518	10,561	15,837
1955	6,910	10,515	15,083	13,660	24,568	22,498	5,533	19,238	6,572	5,201	9,898	6,477	12,131
1956	7,573	10,705	7,321	13,083	38,237	37,355	14,593	14,983	6,680	23,313	9,324	6,281	15,733
1957	5,805	9,652	12,948	8,693	21,326	20,731	5,868	8,779	14,705	12,362	6,544	5,228	10,993
1958	4,780	9,969	12,492	6,078	19,074	18,467	6,294	8,345	12,203	7,533	5,849	6,262	9,714
Mean	6,761	10,311	12,027	13,452	21,781	20,528	7,919	14,885	7,090	9,495	6,818	6,610	11,473

Table 25 - Modified Mean Discharge in c.f.s., Kootenai River at Leonia, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										25,590	9,329	6,815	
1929	8,405	10,393	13,405	15,619	10,688	10,600	6,790	22,531	6,236	7,827	6,771	5,337	10,416
1930	4,259	10,621	15,471	16,126	13,346	12,491	10,531	18,729	6,986	8,244	7,777	6,037	10,890
1931	9,606	15,242	6,486	16,152	14,801	14,230	6,217	9,314	8,124	9,925	5,196	10,520	10,454
1932	12,521	13,101	14,869	14,213	9,61	11,889	9,766	16,836	12,568	7,073	8,611	6,530	11,487
1933	5,314	11,532	14,509	16,087	30,541	29,146	10,459	35,179	16,694	5,910	5,028	9,113	15,714
1934	10,211	13,024	10,692	11,053	48,357	46,806	26,481	15,328	8,152	13,910	7,041	5,601	17,858
1935	4,700	13,356	14,1[illegible]	10,074	26,780	24,287	9,075	33,822	10,421	3,770	5,517	6,343	13,458
1936	4,722	9,909	14,420	11,492	9,170	10,682	10,695	13,765	17,183	9,559	5,449	4,948	10,166
1937	3,689	9,744	14,782	15,521	17,682	8,167	8,463	10,901	6,903	3,865	6,150	6,799	9,336
1938	10,462	9,854	11,961	16,944	25,588	23,340	13,774	16,042	14,480	18,848	6,714	5,824	14,433
1939	5,004	9,908	13,264	14,717	9,782	10,734	10,280	33,539	6,376	4,226	4,574	5,453	10,691
1940	6,064	11,816	14,187	13,192	10,016	11,058	7,598	28,120	4,922	3,717	3,564	6,237	10,067
1941	5,771	10,741	13,763	14,168	9,544	10,373	6,730	11,002	9,016	6,689	6,697	7,727	9,359
1942	5,070	8,173	17,279	16,505	28,434	26,426	10,347	36,388	9,062	5,811	4,146	6,371	14,452
1943	6,067	10,857	13,580	16,027	26,315	25,239	22,171	26,774	11,521	5,517	6,991	6,147	14,695
1944	5,260	9,733	13,020	15,347	10,543	10,181	5,449	16,103	4,661	3,978	6,112	9,561	9,175
1945	10,612	12,527	12,059	10,516	11,264	10,564	10,610	11,493	8,760	3,920	3,416	4,541	9,174
1946	10,163	10,781	3,923	16,764	23,170	23,766	12,275	16,184	11,619	20,403	9,105	8,539	13,849
1947	6,547	10,123	9,377	12,873	29,?50	30,295	13,762	17,562	10,372	18,578	8,293	7,771	14,491
1948	15,393	11,960	13,004	16,421	36,228	34,756	16,050	24,626	14,563	20,264	12,024	7,241	18,514
1949	5,736	9,791	13,019	15,917	10,385	10,386	12,625	16,351	17,955	10,279	6,436	5,574	11,208
1950	5,109	11,440	14,546	16,205	30,270	30,643	9,934	34,468	15,464	6,970	6,700	6,865	15,651
1951	8,603	11,175	10,577	14,454	46,741	39,908	19,550	22,437	9,932	18,790	12,330	10,648	18,597
1952	12,613	11,918	14,144	13,767	25,873	24,119	15,752	15,387	8,759	18,854	9,382	6,807	14,764
1953	5,011	10,035	14,31[illegible]	15,147	24,973	21,940	9,203	31,799	11,485	4,702	7,109	6,688	13,486
1954	5,398	10,260	13,816	15,997	32,675	30,957	11,745	31,741	14,890	28,208	15,908	11,211	18,523
1955	7,203	10,692	15,541	13,992	24,879	22,846	6,808	24,908	14,242	6,841	10,908	6,982	13,775
1956	8,641	12,489	8,861	14,831	39,034	38,767	21,953	28,673	13,450	24,393	10,124	6,803	18,950
1957	6,188	9,994	13,191	8,936	21,64[illegible]	21,903	8,745	18,229	16,815	13,002	6,816	5,362	12,520
1958	4,955	10,135	12,757	6,466	19,808	19,398	8,980	16,115	13,533	8,010	5,924	6,358	10,979
Mean	7,310	11,044	12,833	14,184	22,580	21,530	11,761	21,812	11,171	10,736	7,360	6,998	13,277

Table 26 - Observed Mean Discharge in c.f.s., Moyie River at Eileen, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										763	262	151	
1929	228	187	122	89	95	183	560	2,480	1,850	363	128	100	534
1930	96	89	93	83	126	255	1,880	2,160	1,570	400	145	104	584
1931	120	128	102	113	147	273	719	2,240	674	246	98	88	415
1932	88	128	121	138	287	474	1,860	4,360	2,570	429	139	108	892
1933	135	388	506	301	202	275	1,710	3,910	4,240	803	206	175	1,072
1934	402	821	991	942	708	901	4,281	3,933	1,081	264	109	93	1,211
1935	109	347	234	323	403	385	1,264	3,574	2,407	641	214	127	837
1936	124	132	114	114	90	199	2,200	2,865	813	200	91	95	587
1937	83	65	92	70	86	130	739	2,910	2,238	502	181	124	604
1938	158	440	354	406	284	615	2,809	4,341	2,524	517	160	113	1,062
1939	126	126	130	201	127	402	1,875	2,833	1,320	477	118	91	654
1940	106	152	264	152	153	486	1,628	2,467	800	167	88	89	547
1941	122	161	154	142	144	578	1,500	1,727	789	282	122	354	507
1942	672	639	1,444	357	266	261	1,880	3,254	3,043	1,201	325	176	1,130
1943	145	201	224	186	193	333	3,574	3,326	2,933	968	229	123	1,036
1944	124	130	117	102	97	109	575	1,441	774	223	97	77	323
1945	84	94	88	95	116	148	521	3,487	1,914	408	117	96	601
1946	106	211	205	189	169	463	2,498	4,930	2,321	606	156	137	1,003
1947	170	170	229	243	432	743	2,661	4,343	1,733	398	176	173	958
1948	1,102	843	392	303	279	301	1,875	5,205	3,343	745	351	180	1,245
1949	188	180	165	155	208	322	2,275	4,357	1,175	308	143	117	803
1950	144	296	441	209	236	485	1,689	4,837	4,401	1,205	271	144	1,200
1951	421	790	1,032	732	1,189	575	2,325	4,901	2,280	833	233	230	1,295
1952	516	388	477	284	266	288	2,748	3,645	1,809	600	190	120	944
1953	98	95	100	247	348	316	1,181	3,821	2,940	594	177	116	837
1954	109	189	182	170	199	327	1,305	5,481	3,566	1,454	310	245	1,134
1955	263	403	344	222	188	165	654	3,190	3,882	1,161	265	138	908
1956	418	741	509	429	315	499	3,030	6,089	2,886	620	195	122	1,322
1957	164	156	164	99	141	316	1,343	4,889	1,423	313	147	94	776
1958	110	135	138	136	201	335	1,069	3,998	1,061	279	105	91	642
Mean	224	294	318	241	257	371	1,808	3,700	2,145	574	176	135	854

Table 27 - Modified Mean Discharge in c.f.s., Kootenai River at Porthill, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										27,190	9,729	6,695	
1929	7,615	10,163	13,345	15,549	10,578	10,940	7,340	24,931	10,836	9,627	6,901	5,297	11,127
1930	4,559	10,861	15,700	16,346	13,626	12,931	14,331	33,029	9,686	9,244	8,157	6,197	12,912
1931	9,926	15,522	6,716	16,492	15,241	14,860	7,787	14,014	10,024	10,825	5,476	10,780	11,446
1932	12,761	13,451	15,099	14,473	10,566	13,299	14,466	25,336	18,368	8,673	9,051	6,790	13,547
1933	5,504	12,542	15,649	16,787	30,981	30,226	13,359	44,479	25,494	9,810	5,628	9,223	18,237
1934	10,491	14,844	12,872	13,613	50,123	48,916	34,541	24,848	13,452	14,720	7,213	5,724	20,748
1935	4,998	14,420	14,784	10,871	27,926	25,165	11,095	41,542	17,491	6,230	6,167	6,701	15,550
1936	4,996	10,158	14,674	11,715	9,412	11,150	15,475	20,865	19,633	10,069	5,719	5,149	11,585
1937	3,907	9,911	15,188	15,698	17,856	8,468	9,915	17,061	14,383	5,845	6,679	7,037	10,947
1938	10,893	11,000	13,003	18,140	24,311	24,841	18,474	23,142	23,220	21,148	7,121	6,074	16,742
1939	5,445	10,202	13,621	15,257	10,114	11,670	13,760	39,589	9,516	5,776	4,955	5,728	12,178
1940	6,292	12,190	14,863	13,609	10,510	12,388	11,628	33,700	7,332	4,087	3,795	6,424	11,428
1941	5,975	11,069	14,165	14,487	9,845	11,465	9,680	15,192	11,196	7,369	7,024	8,462	10,504
1942	6,608	9,671	20,519	17,313	29,128	27,106	13,897	42,468	15,022	8,941	4,906	6,669	16,814
1943	6,533	11,567	14,230	16,470	26,751	25,898	29,161	33,354	19,921	10,347	8,141	6,440	17,331
1944	5,653	10,196	13,457	15,737	10,877	10,486	6,430	18,723	7,021	4,309	6,364	9,656	9,921
1945	10,920	12,923	12,666	10,937	11,755	11,187	11,794	18,233	13,800	5,560	3,801	4,651	10,676
1946	10,493	11,320	4,379	17,202	23,573	24,548	16,015	25,604	18,979	22,663	9,485	8,839	16,055
1947	7,010	10,509	9,990	13,401	30,948	32,000	17,852	26,652	15,282	19,778	8,860	8,159	16,627
1948	18,163	14,286	14,029	17,200	37,009	35,539	19,380	24,746	29,223	24,994	12,874	7,618	21,209
1949	6,230	10,340	13,444	16,357	10,829	11,131	27,695	25,751	22,755	11,229	6,829	5,795	14,030
1950	5,467	12,324	15,799	16,815	30,938	32,009	13,174	43,908	26,534	12,550	7,410	7,286	18,626
1951	10,026	13,333	13,141	16,417	44,599	41,323	23,605	33,447	16,122	22,740	13,050	11,268	21,460
1952	14,053	12,919	15,438	14,541	26,958	24,954	19,652	24,267	15,039	21,644	9,752	7,183	17,185
1953	5,368	10,375	14,642	16,074	26,053	22,833	11,085	40,259	18,745	7,652	7,559	7,001	15,594
1954	5,687	10,795	14,393	16,508	33,220	31,980	14,635	40,451	23,970	34,128	17,018	11,751	21,178
1955	7,813	11,682	16,350	14,517	25,451	23,354	8,245	30,318	24,262	12,091	11,948	7,285	16,068
1956	9,918	14,274	10,166	16,042	39,870	39,950	27,783	34,663	26,810	28,963	10,924	7,087	22,143
1957	6,821	10,433	13,793	9,365	22,060	23,034	10,865	28,539	22,795	13,982	7,134	5,466	14,485
1958	5,330	10,459	13,096	6,832	20,452	20,443	11,110	23,025	18,223	8,730	6,019	6,510	12,464
Mean	7,849	11,791	13,640	14,826	23,052	22,470	15,474	29,071	17,504	13,124	7,865	7,275	15,328

Table 28 - Modified Mean Discharge in c.f.s., Blackfoot River near Bonner, Montana

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										3,427	1,718	702	
1929	675	656	562	498	472	529	262	1,790	5,007	1,966	1,018	617	1,172
1930	518	461	469	407	418	481	1,316	2,707	3,345	1,604	941	611	1,109
1931	560	558	527	457	465	541	572	2,523	3,027	1,339	809	584	999
1932	526	487	493	452	428	771	1,477	4,271	5,445	2,613	1,249	667	1,575
1933	569	627	706	607	559	578	469	2,523	8,130	3,681	1,531	693	1,724
1934	693	1,391	1,015	1,161	955	1,135	3,266	6,587	4,398	1,722	983	608	1,997
1935	529	715	655	568	643	701	524	2,569	5,759	2,527	1,257	653	1,426
1936	535	473	468	428	396	439	883	5,087	4,255	1,486	848	575	1,325
1937	494	435	438	396	380	394	110	1,847	4,181	2,011	1,023	610	1,029
1938	523	517	524	501	495	543	2,250	4,581	4,708	1,350	666	546	1,435
1939	500	460	501	473	406	680	2,748	5,955	2,910	1,277	598	498	1,423
1940	474	484	438	390	445	670	1,644	3,034	1,717	662	445	400	901
1941	419	437	399	357	370	491	537	1,088	1,223	577	381	371	555
1942	418	469	462	395	404	505	1,508	2,963	3,308	1,208	614	461	1,061
1943	449	567	531	439	447	678	4,727	4,897	7,594	3,304	1,069	721	2,118
1944	643	621	531	487	464	485	677	2,067	1,994	1,044	609	450	840
1945	428	445	346	462	449	511	668	3,269	3,938	1,367	654	520	1,090
1946	524	625	534	448	582	700	2,389	4,428	3,421	1,283	733	588	1,366
1947	737	810	982	734	705	1,405	2,912	7,899	5,427	1,834	934	744	2,101
1948	875	870	715	680	651	648	2,239	8,241	7,175	2,067	1,135	751	2,172
1949	643	615	463	416	447	534	1,921	5,949	3,307	1,026	597	522	1,375
1950	502	521	428	353	506	731	1,396	4,347	7,317	3,323	1,448	791	1,808
1951	763	1,002	862	748	922	804	2,907	7,973	5,621	2,727	1,142	939	2,207
1952	966	801	623	543	561	536	3,227	6,764	3,117	1,183	739	554	1,637
1953	517	529	482	570	592	585	899	3,572	9,101	2,594	947	703	1,756
1954	614	603	561	503	528	593	1,516	6,170	5,865	3,177	997	788	1,833
1955	725	660	599	536	492	469	797	3,299	5,293	2,817	1,092	690	1,459
1956	628	620	621	662	540	840	2,840	6,862	5,620	1,764	915	640	1,881
1957	626	622	649	522	517	692	1,241	7,158	4,273	1,190	668	599	1,570
1958	611	570	551	412	484	591	1,460	5,987	4,717	1,415	730	632	1,518
Mean	589	622	571	524	524	642	1,646	4,547	4,706	1,871	892	618	1,479

Table 29 - Modified Mean Discharge in c.f.s., Clark Fork above Missoula, Montana

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										4,584	1,991	1,724	
1929	1,606	1,550	1,332	1,163	1,214	2,150	2,580	6,251	7,549	2,156	1,027	961	2,464
1930	1,326	1,322	1,498	836	2,012	1,790	5,010	6,261	3,999	1,506	1,107	1,192	2,318
1931	1,536	1,372	1,208	1,254	1,222	1,400	1,730	2,941	2,129	794	723	773	1,424
1932	952	932	948	874	997	1,500	2,480	7,351	6,569	2,026	1,047	907	2,216
1933	1,146	1,352	948	1,004	672	1,370	2,270	6,671	13,769	2,676	1,257	1,282	2,866
1934	1,573	2,385	2,249	2,531	2,255	3,071	10,080	8,516	4,245	1,454	898	867	3,341
1935	1,251	1,397	1,226	1,126	1,164	1,343	1,903	5,079	5,449	1,850	872	691	1,948
1936	870	1,110	941	909	839	1,517	4,158	8,167	4,876	1,373	903	1,012	2,224
1937	1,077	1,079	998	610	852	1,037	1,615	3,917	3,180	1,212	787	645	1,420
1938	937	894	943	834	951	1,257	2,641	7,921	9,419	4,710	1,435	1,113	2,761
1939	1,345	1,437	1,191	1,039	870	2,009	3,387	7,306	4,107	1,720	870	897	2,189
1940	1,178	1,140	1,061	915	1,123	1,676	2,898	4,742	2,888	1,021	692	770	1,676
1941	1,194	1,100	1,098	982	926	1,185	1,191	1,986	2,987	1,359	866	1,138	1,335
1942	1,351	1,376	1,379	1,045	1,120	1,558	4,029	6,661	8,385	2,688	1,210	1,047	2,655
1943	1,208	1,512	1,441	1,213	1,452	1,797	8,771	8,942	13,819	5,910	2,019	1,403	4,121
1944	1,564	1,629	1,203	1,074	1,103	1,439	1,716	3,722	5,454	2,704	1,517	1,147	2,023
1945	1,209	1,232	882	1,196	1,253	1,366	1,585	5,441	7,503	2,461	1,183	1,095	2,201
1946	1,340	1,486	1,280	1,290	1,248	1,780	3,720	6,284	5,125	2,240	1,237	1,452	2,376
1947	2,104	2,043	2,261	1,615	1,986	2,951	4,897	12,971	9,199	3,133	1,676	1,587	3,878
1948	2,029	1,996	1,766	1,984	1,772	1,811	4,943	15,961	15,389	4,749	2,493	1,581	4,708
1949	1,712	1,724	1,245	1,099	1,334	1,799	4,489	10,081	6,811	2,063	1,247	1,420	2,924
1950	1,453	1,451	1,219	1,098	1,466	1,892	3,206	7,160	13,309	5,494	2,539	1,739	3,503
1951	1,972	2,123	1,936	1,620	2,241	2,073	5,250	14,041	10,399	4,995	2,182	2,070	4,250
1952	2,234	1,940	1,587	1,351	1,463	1,644	6,193	12,191	5,818	2,387	1,354	1,304	3,293
1953	1,335	1,343	1,265	1,572	1,438	1,470	1,947	5,673	16,259	4,150	1,694	1,439	3,293
1954	1,408	1,454	1,394	1,194	1,527	1,581	2,871	8,951	8,810	4,594	1,788	1,507	3,097
1955	1,572	1,490	1,192	1,167	1,121	1,133	1,988	5,531	8,958	6,300	1,989	1,334	2,822
1956	1,568	1,531	2,068	1,462	1,176	2,691	5,685	12,031	9,096	3,103	1,742	1,436	3,637
1957	1,551	1,588	1,570	1,050	1,403	1,802	2,502	11,141	7,646	2,084	1,210	1,277	2,910
1958	1,579	1,480	1,348	1,167	1,318	1,527	2,860	10,581	8,419	3,172	1,415	1,437	3,034
Mean	1,439	1,482	1,356	1,209	1,317	1,721	3,620	7,816	7,719	2,869	1,366	1,217	2,761

Table 30 - Modified Mean Discharge in c.f.s., Clark Fork below Missoula, Montana

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										9,433	3,250	2,940	
1929	2,973	2,751	2,378	1,979	1,942	5,533	2,313	7,282	16,498	5,743	2,293	2,160	4,492
1930	2,083	2,125	2,459	1,392	2,910	2,867	9,604	11,754	8,914	2,775	1,600	1,936	4,196
1931	2,923	2,615	1,919	1,812	1,920	2,117	2,954	7,904	5,204	1,245	760	1,176	2,716
1932	1,583	1,515	1,539	1,422	1,650	2,397	4,224	14,854	14,234	4,185	1,610	1,476	4,226
1933	1,963	2,345	1,499	1,672	1,120	2,037	4,024	11,154	27,134	5,505	1,700	1,686	5,146
1934	2,723	4,175	3,969	4,412	4,242	6,035	16,494	15,054	7,777	2,751	1,306	1,385	5,856
1935	2,415	2,870	2,226	2,007	2,045	2,428	3,550	10,044	10,864	3,373	1,213	996	3,673
1936	1,498	1,867	1,589	1,504	1,331	2,489	8,408	17,144	10,364	2,192	1,145	1,560	4,259
1937	1,702	1,774	1,644	883	1,259	1,750	2,373	8,260	7,181	1,928	1,067	895	2,565
1938	1,416	1,496	1,733	1,524	1,508	2,241	5,334	14,994	18,824	7,144	1,907	1,561	4,982
1939	2,254	2,439	2,298	2,008	1,722	3,210	6,467	15,704	8,191	2,874	1,193	1,353	4,157
1940	1,866	1,837	1,871	1,554	1,930	2,658	5,216	10,094	5,957	1,519	952	1,148	3,051
1941	2,331	1,965	1,831	1,507	1,499	1,779	2,296	5,067	6,546	2,238	1,305	2,610	2,582
1942	3,047	3,075	3,179	2,065	2,002	2,582	6,916	12,234	16,484	4,970	1,747	1,711	5,003
1943	2,340	2,877	2,711	2,350	2,572	3,799	15,614	16,104	25,374	12,395	3,212	2,335	7,639
1944	2,661	2,918	1,976	1,714	1,725	2,033	2,630	7,456	11,554	4,018	2,017	1,605	3,523
1945	1,965	2,139	1,507	1,932	1,913	1,956	2,500	10,484	14,274	4,413	1,544	1,610	3,855
1946	2,371	2,625	2,142	2,162	1,966	2,789	6,754	12,624	10,614	4,536	1,970	2,792	4,452
1947	4,504	4,285	4,645	2,956	3,339	4,721	8,270	25,764	17,994	5,893	2,786	2,784	7,342
1948	4,137	3,750	3,454	3,256	3,038	3,103	7,577	27,624	30,034	7,961	3,858	2,402	8,350
1949	2,923	2,837	2,094	1,614	2,265	3,156	8,346	21,514	14,414	3,929	1,986	2,357	5,632
1950	2,792	2,791	2,493	2,157	2,794	3,392	5,431	12,504	26,554	11,465	4,129	2,738	6,604
1951	4,042	4,356	3,681	2,892	4,068	3,533	9,391	23,814	18,664	9,265	3,315	3,233	7,534
1952	4,001	3,277	2,583	2,353	2,579	2,914	9,939	21,834	13,124	4,585	2,104	2,076	5,953
1953	2,289	2,194	1,958	2,520	2,384	2,323	3,488	9,421	26,494	8,160	2,463	2,074	5,472
1954	2,125	2,399	2,496	2,167	2,698	2,828	5,368	17,204	16,804	9,547	2,808	2,578	5,766
1955	2,814	2,589	2,068	1,920	1,832	1,887	3,312	10,994	19,974	11,835	2,683	2,021	5,338
1956	2,632	2,918	3,963	2,855	2,219	4,251	10,914	24,014	19,444	5,816	2,696	2,281	7,006
1957	2,699	2,714	2,658	1,888	2,559	3,188	4,121	21,264	16,204	3,805	1,654	1,823	5,395
1958	2,608	2,463	2,140	1,920	2,227	2,598	4,578	21,554	15,174	4,903	1,994	2,009	5,365
Mean	2,589	2,666	2,423	2,080	2,242	2,953	6,280	14,857	15,362	5,366	2,034	1,946	5,066

Table 31 - Observed Mean Discharge in c.f.s., Flathead River at Flathead, British Columbia

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										1,746	618	439	
1929	436	334	215	169	131	155	275	2,660	2,970	661	296	215	712
1930	178	218	177	134	108	144	1,130	2,420	2,120	622	289	208	647
1931	176	276	202	153	128	157	318	2,440	1,190	387	188	164	484
1932	147	234	187	152	113	206	756	4,050	3,680	892	394	261	924
1933	301	401	278	212	168	165	534	3,140	5,480	1,270	423	318	1,058
1934	757	707	411	426	333	284	2,960	4,840	1,980	603	275	192	1,151
1935	191	574	257	196	202	191	356	3,250	3,690	1,100	374	230	886
1936	198	174	134	142	99	135	1,080	3,630	1,420	406	220	175	653
1937	138	124	163	130	92	126	299	3,110	2,210	654	308	183	632
1938	273	452	200	170	141	158	1,720	4,340	3,800	931	383	249	1,070
1939	226	218	190	159	103	187	1,680	3,170	1,440	594	246	204	704
1940	190	225	192	132	117	198	926	3,110	1,390	405	225	227	613
1941	186	220	176	141	105	160	711	1,930	934	422	212	468	474
1942	623	338	344	205	142	146	1,430	3,360	2,700	1,180	463	344	943
1943	272	298	233	179	149	160	2,195	2,450	2,850	1,240	415	248	891
1944	212	176	180	136	92	129	550	1,670	1,050	383	230	214	419
1945	225	164	175	157	118	153	370	3,200	2,410	763	284	242	692
1946	228	391	234	180	148	207	1,420	2,820	3,170	988	370	269	870
1947	302	359	262	193	189	250	1,310	4,680	2,330	715	376	360	948
1948	1,280	643	230	195	156	168	979	5,580	3,690	954	654	289	1,239
1949	239	196	179	141	127	168	1,280	4,110	1,910	601	291	240	794
1950	230	388	251	184	168	228	843	3,530	4,570	1,630	543	271	1,072
1951	619	515	361	271	350	210	1,253	5,080	3,590	1,870	596	785	1,297
1952	1,140	466	330	230	210	190	1,470	3,150	1,790	811	354	229	866
1953	174	153	181	276	195	173	597	3,430	4,980	1,410	466	279	1,028
1954	219	315	215	181	180	177	407	5,050	4,600	2,420	654	439	1,245
1955	387	378	279	198	151	159	284	2,370	4,670	1,360	424	243	909
1956	608	509	271	210	150	186	930	5,310	4,100	1,130	383	246	1,172
1957	290	228	180	124	113	142	506	4,930	2,300	565	266	181	825
1958	189	199	164	154	161	160	478	4,770	1,760	612	268	224	768
Mean	354	329	228	184	155	176	968	3,586	2,826	919	362	273	863

Table 32 - Observed Mean Discharge in c.f.s., Flathead River near Columbia Falls, Montana

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										6,719	2,327	1,588	
1929	1,418	1,168	787	658	582	667	1,660	8,310	9,380	2,690	1,140	1,094	2,469
1930	1,060	601	520	426	486	591	2,893	7,110	6,760	2,720	1,410	923	2,131
1931	876	677	562	561	614	729	2,520	8,810	4,820	1,770	1,411	993	2,038
1932	662	678	527	421	760	1,510	3,970	12,000	12,400	3,860	1,480	906	3,265
1933	939	1,084	1,218	900	737	724	3,160	10,000	17,100	7,203	2,138	1,470	3,895
1934	1,492	3,309	2,130	1,452	1,438	1,372	5,059	14,680	7,287	2,425	1,186	758	3,560
1935	792	2,010	1,018	1,037	1,011	867	2,012	7,721	11,690	4,592	1,498	936	2,934
1936	779	628	394	398	400	554	5,619	12,130	5,496	1,687	898	668	2,475
1937	518	420	416	325	377	435	1,374	9,039	8,422	2,760	1,185	708	2,173
1938	814	1,230	713	757	618	766	4,562	11,910	12,360	3,935	1,364	933	3,337
1939	824	673	613	655	480	801	4,866	9,567	5,609	2,597	1,071	777	2,387
1940	647	649	852	597	610	782	2,787	8,599	4,984	1,582	808	780	1,977
1941	823	645	562	524	465	649	2,824	5,757	3,353	1,526	747	1,340	1,606
1942	1,717	1,269	2,268	1,004	665	575	3,209	8,650	8,638	4,802	1,695	1,125	2,997
1943	881	871	849	668	747	691	6,877	7,695	9,609	5,722	1,702	910	3,105
1944	745	616	537	406	370	406	1,288	4,986	4,124	1,525	861	705	1,383
1945	776	657	512	486	448	490	845	8,245	8,449	3,145	1,084	891	2,177
1946	829	1,246	828	640	614	900	4,964	13,490	10,430	3,744	1,445	958	3,351
1947	1,116	944	723	502	788	940	4,628	13,780	9,104	3,487	1,669	1,386	3,268
1948	3,224	1,844	961	737	659	590	2,892	12,420	11,300	3,339	2,338	1,038	3,451
1949	767	640	549	545	564	607	4,048	12,260	7,120	2,628	1,370	953	2,683
1950	912	1,463	1,377	847	753	979	2,184	9,783	14,800	7,255	2,426	1,136	3,670
1951	1,970	1,948	1,812	1,341	1,813	1,117	4,020	14,520	10,060	6,525	2,121	2,275	4,141
1952	3,650	1,705	1,184	816	765	668	6,075	10,790	6,546	3,089	1,421	891	3,139
1953	649	506	505	864	871	661	2,218	9,325	14,030	5,455	1,829	1,034	3,167
1954	725	880	763	635	663	665	1,610	15,160	14,230	9,262	2,850	2,048	4,146
1955	1,662	1,506	1,072	772	581	573	1,104	6,438	12,960	5,587	1,790	984	2,925
1956	2,027	1,914	1,225	954	673	833	4,047	13,860	12,960	4,473	1,731	1,042	3,816
1957	1,195	868	742	532	500	668	1,963	15,010	8,119	2,565	1,195	740	2,860
1958	787	781	591	475	591	777	2,470	13,430	6,177	2,111	1,109	945	2,535
Mean	1,176	1,115	894	698	688	753	3,265	10,516	9,277	3,802	1,499	1,045	2,894

Table 33 - Modified Mean Discharge in c.f.s., South Fork Flathead River near Columbia Falls, Montana

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										5,470	1,390	1,625	
1929	4,998	8,000	9,902	453	430	606	2,050	401	400	1,132	711	1,403	2,553
1930	9,460	10,369	2,185	999	2,131	400	6,302	400	400	402	590	2,748	3,019
1931	7,502	8,793	10,661	694	2,030	2,548	3,240	401	400	400	4,001	9,448	4,180
1932	10,685	9,417	4,943	552	1,440	2,130	400	400	400	400	400	400	2,637
1933	400	400	3,306	3,001	9,556	400	11,819	1,020	4,410	1,948	1,330	1,780	3,215
1934	6,005	4,268	400	1,622	2,042	9,029	21,210	3,537	3,043	1,797	675	1,449	4,579
1935	7,493	6,708	5,323	400	400	400	8,298	2,419	3,067	2,342	864	1,484	3,272
1936	6,108	9,118	6,698	400	1,136	2,142	1,633	2,322	3,430	1,450	576	1,408	3,036
1937	7,859	9,987	4,150	884	4,672	2,433	6,478	400	400	400	400	400	3,181
1938	5,646	4,952	1,976	400	400	400	1,181	3,153	2,713	2,396	793	1,478	2,133
1939	6,431	8,390	7,829	400	3,243	2,141	1,335	2,579	2,542	2,340	732	1,450	3,283
1940	6,963	8,164	7,245	400	400	400	400	400	400	2,168	1,569	586	2,436
1941	6,843	7,561	5,565	400	515	400	400	400	471	2,513	2,840	3,347	2,618
1942	1,434	5,677	400	400	400	1,870	1,449	2,444	2,567	2,339	914	1,594	1,791
1943	6,881	7,518	3,949	7,756	1,037	400	13,783	2,008	3,617	1,958	1,570	1,743	4,354
1944	5,577	8,352	8,800	476	400	766	2,160	400	3,302	4,249	3,608	8,001	3,842
1945	8,347	7,827	6,984	400	400	3,097	5,829	400	400	400	400	400	2,920
1946	419	5,755	4,415	400	400	400	400	400	1,202	2,150	1,030	1,625	1,551
1947	5,622	8,985	400	4,179	2,835	400	18,731	3,144	3,080	1,728	1,128	1,888	4,314
1948	2,349	4,673	6,220	1,306	3,725	400	19,915	2,737	3,307	1,985	1,149	1,548	4,076
1949	4,565	7,727	4,765	1,206	3,752	400	2,201	3,451	3,196	1,740	662	1,532	2,918
1950	6,876	7,234	5,086	4,176	2,399	400	18,570	888	3,850	1,588	2,182	1,847	4,573
1951	5,520	3,577	689	2,184	400	8,254	20,493	2,912	2,970	1,637	1,448	2,038	4,344
1952	3,933	8,878	4,775	400	2,536	400	9,777	3,112	2,723	2,295	775	1,482	3,404
1953	6,413	9,356	6,428	400	400	400	7,625	2,425	3,963	1,942	1,143	1,577	3,508
1954	4,560	7,991	5,048	1,453	2,562	400	19,621	1,811	3,280	1,804	1,617	1,595	4,284
1955	5,915	6,185	7,494	400	4,984	400	6,568	1,496	3,400	2,303	1,136	1,612	3,468
1956	5,695	4,634	400	609	5,197	4,416	20,316	2,948	3,093	2,164	1,063	1,640	4,310
1957	5,047	8,257	5,171	400	2,261	400	6,198	3,712	3,033	1,966	687	1,568	3,216
1958	6,852	8,255	7,735	400	400	400	1,253	3,653	2,622	1,099	880	2,546	3,022
Mean	5,747	7,234	4,965	1,238	2,083	1,554	7,988	1,859	2,389	1,768	1,229	2,054	3,3

Table 34 - Modified Mean Discharge in c.f.s., Flathead River at Columbia Falls, Montana

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										18,790	4,880	3,710	
1929	7,963	10,140	11,384	1,720	1,530	1,930	5,390	18,501	18,600	6,612	3,050	2,880	7,504
1930	10,615	11,267	3,133	2,030	3,263	1,550	17,912	19,120	14,170	5,320	2,940	4,300	7,964
1931	9,160	10,323	11,703	1,710	3,365	4,018	7,980	19,001	10,440	3,720	5,683	11,007	8,196
1932	11,990	10,867	5,975	1,340	2,990	5,510	19,380	28,300	25,700	8,220	3,430	2,361	10,502
1933	2,208	3,330	6,006	4,131	10,526	1,622	18,109	20,420	41,310	13,348	4,790	4,120	10,765
1934	11,223	11,190	5,931	6,157	5,103	12,782	41,650	31,657	16,173	6,644	2,824	2,819	12,854
1935	8,868	11,366	7,218	2,960	2,726	1,936	12,467	23,699	25,987	11,119	3,745	3,120	9,618
1936	7,314	10,168	7,498	1,186	1,958	3,297	11,091	27,992	15,700	5,070	2,410	2,700	8,045
1937	8,858	10,808	4,918	1,546	5,275	3,114	9,486	19,620	18,990	6,249	2,582	1,725	7,757
1938	7,107	7,155	3,347	1,944	1,634	1,942	11,059	26,633	24,853	9,403	3,353	3,183	8,490
1939	8,059	9,774	9,302	1,787	4,030	4,054	12,237	25,619	14,990	8,149	2,916	2,878	8,673
1940	8,078	9,274	8,676	1,388	1,406	2,063	6,409	17,770	10,869	5,276	3,065	2,068	6,380
1941	8,352	8,745	6,647	1,384	1,376	1,649	5,880	11,857	7,766	5,539	4,263	5,736	5,788
1942	4,764	8,105	5,379	2,750	1,952	3,035	9,029	18,718	18,620	11,266	3,946	3,621	7,621
1943	8,421	9,394	5,996	9,360	2,823	2,102	28,508	18,518	26,057	14,096	4,949	3,524	11,151
1944	7,132	9,605	9,839	1,317	1,161	1,576	5,317	12,615	12,278	7,436	5,443	9,574	6,948
1945	9,971	9,166	7,999	1,496	1,466	4,205	7,952	18,460	18,160	7,085	2,635	2,240	7,600
1946	2,243	8,846	6,311	1,906	1,699	2,400	10,764	25,870	20,412	9,605	3,883	3,543	8,146
1947	8,208	11,346	2,263	5,363	4,503	2,713	29,245	31,894	22,510	9,350	4,562	4,501	11,367
1948	8,401	8,047	8,122	2,834	4,925	1,603	26,313	30,437	27,427	8,412	5,247	3,429	11,246
1949	5,920	8,833	5,696	2,117	4,524	1,503	9,721	27,521	17,690	6,648	3,145	3,275	8,058
1950	8,571	10,215	7,881	5,772	3,916	2,431	23,454	21,238	35,580	17,011	6,785	4,120	12,250
1951	9,951	7,991	4,956	5,151	4,145	10,422	28,366	31,512	23,090	15,279	5,755	6,367	12,779
1952	10,811	12,243	7,277	2,064	3,963	1,682	21,954	26,195	16,776	8,847	3,713	3,211	9,887
1953	7,587	10,299	7,249	2,269	2,537	1,881	12,881	21,617	32,607	13,417	4,851	3,498	10,067
1954	5,770	9,446	6,466	2,549	3,812	1,841	23,126	32,242	31,264	20,044	6,885	5,367	12,418
1955	9,198	9,263	9,707	1,957	6,254	1,555	8,848	15,263	30,220	13,893	3,999	3,506	9,460
1956	10,043	8,736	2,968	2,636	6,473	5,776	28,076	30,312	28,896	11,134	4,519	3,754	11,914
1957	7,570	10,029	6,746	1,580	3,455	1,904	10,557	34,512	20,356	7,295	3,054	2,944	9,194
1958	8,123	9,423	8,756	9,190	9,563	8,613	22,094	21,265	40,932	17,644	5,576	8,420	14,104
Mean	8,083	9,513	6,845	2,986	3,745	3,357	16,175	23,613	22,281	9,771	4,133	4,126	9,552

Table 35 - Modified Mean Discharge in c.f.s., Flathead River near Polson, Montana

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										22,560	6,245	5,463	
1929	11,999	14,187	14,183	12,318	4,368	3,280	4,835	13,928	14,423	6,822	2,394	4,777	8,991
1930	14,202	14,197	6,242	10,992	6,062	2,730	10,365	14,170	9,493	5,204	1,879	6,888	8,537
1931	13,092	13,797	13,962	11,332	6,064	5,178	6,489	13,977	3,403	3,426	6,002	13,581	9,216
1932	14,187	14,187	13,875	6,917	3,332	5,751	8,371	21,410	22,300	9,110	3,418	5,054	10,679
1933	5,891	6,888	8,808	10,274	13,657	7,256	9,754	19,645	42,020	15,018	5,175	5,546	12,446
1934	14,201	13,320	9,981	11,611	8,688	21,223	31,669	43,133	14,283	7,483	2,510	4,154	15,234
1935	12,631	14,199	10,448	9,437	6,685	6,056	8,750	19,687	25,437	12,469	3,627	4,244	11,154
1936	10,710	13,768	10,275	10,662	5,220	4,293	7,280	25,223	13,450	4,917	1,719	3,960	9,308
1937	12,369	14,044	7,247	11,298	6,818	5,134	8,163	10,953	15,414	6,442	2,206	4,010	8,671
1938	10,590	10,296	5,538	10,757	4,780	2,952	6,131	20,433	22,353	9,565	2,662	4,779	9,255
1939	11,062	12,857	11,425	11,821	6,553	5,254	8,152	22,494	11,810	8,479	2,142	4,804	9,768
1940	10,990	12,304	10,815	10,521	5,057	3,334	5,016	10,417	6,583	5,150	2,243	4,372	7,247
1941	11,543	11,559	8,810	11,627	3,911	2,519	5,114	2,701	1,684	4,883	4,050	7,773	6,366
1942	8,173	11,668	7,247	12,830	5,452	3,820	6,830	13,216	17,640	13,056	3,814	5,295	9,103
1943	11,810	12,730	8,832	14,188	8,242	6,096	17,594	24,930	26,467	17,996	5,056	4,812	13,247
1944	10,774	13,524	12,315	11,788	3,487	2,295	4,918	6,872	4,081	6,920	5,430	11,521	7,843
1945	12,732	12,545	14,079	8,203	2,882	5,109	7,269	9,589	16,720	8,475	2,053	4,500	8,710
1946	5,758	12,235	9,475	11,684	4,647	3,732	7,859	23,370	19,782	11,225	3,617	5,015	9,895
1947	11,881	14,201	5,084	12,115	7,343	9,940	19,057	37,731	23,244	10,770	5,093	6,391	13,599
1948	9,546	12,044	12,987	8,856	9,126	9,631	16,635	35,786	30,876	11,177	6,537	4,893	14,012
1949	9,370	12,855	8,513	12,547	7,104	4,138	6,755	24,740	15,010	7,092	2,974	4,962	9,690
1950	11,718	13,648	10,386	12,161	7,095	8,809	15,774	22,321	37,100	23,361	8,468	5,471	14,719
1951	13,529	9,822	8,259	10,913	6,555	19,620	23,034	37,769	24,711	19,379	6,208	8,329	15,744
1952	13,679	14,203	13,752	10,192	8,132	6,962	11,891	34,023	16,347	10,224	3,526	4,696	12,331
1953	11,165	13,509	9,625	10,689	4,789	5,672	7,278	19,121	33,653	15,508	4,855	4,450	11,716
1954	8,865	13,195	9,171	8,128	7,059	8,495	14,878	33,678	32,967	25,312	7,950	6,695	14,738
1955	12,870	12,182	13,151	9,727	10,385	3,838	7,174	7,802	29,400	16,418	4,706	4,657	11,006
1956	13,413	10,812	5,255	7,246	10,837	12,277	21,112	36,909	30,404	13,545	4,867	5,250	14,318
1957	10,766	13,856	9,689	9,372	7,429	5,744	6,522	29,469	21,197	7,963	2,624	4,287	10,762
1958	11,486	13,006	11,307	8,564	4,546	6,888	3,135	26,273	14,126	6,968	2,150	4,273	9,442
Mean	11,367	12,721	10,025	10,625	6,544	6,601	10,593	22,059	19,879	10,812	3,999	5,648	10,906

AD-A036 546 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/8
COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
APR 70 G L BODHAINE, H D HAFTERSON

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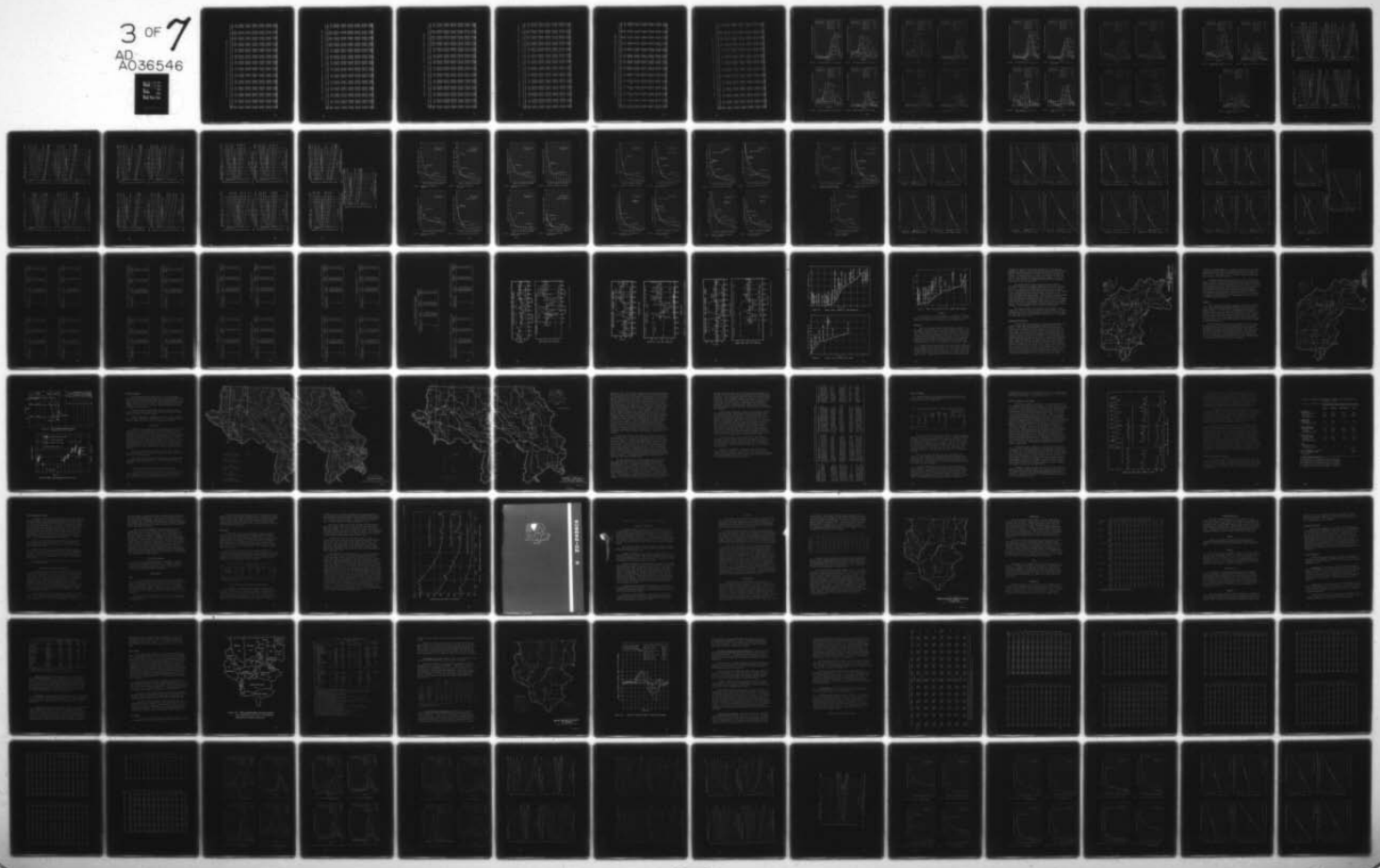


Table 36 - Modified Mean Discharge in c.f.s., Clark Fork near Plains, Montana

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										34,520	12,260	10,197	
1929	16,627	18,530	18,192	14,912	6,790	7,102	9,696	28,048	31,693	13,592	4,731	6,944	14,782
1930	17,225	15,135	9,471	13,296	10,129	6,197	23,045	29,480	21,063	9,482	4,096	9,614	14,181
1931	17,085	17,550	17,011	14,176	8,631	7,955	10,180	24,077	10,663	5,624	7,037	15,132	12,957
1932	16,490	16,710	16,474	9,151	6,524	9,571	16,736	45,200	42,980	16,210	6,346	5,977	17,388
1933	8,809	10,968	11,707	13,263	16,189	10,613	16,175	37,245	78,320	25,208	8,796	9,277	20,494
1934	19,417	20,820	20,691	22,056	17,306	31,887	57,329	63,263	25,233	10,400	4,949	6,677	25,038
1935	16,137	18,542	14,160	13,199	10,318	9,972	14,980	35,507	41,587	18,789	6,196	6,358	17,166
1936	13,420	16,548	12,543	12,749	7,684	9,167	19,851	48,113	28,800	8,854	3,99[illegible]	6,591	15,712
1937	15,353	16,993	9,849	13,075	9,158	8,067	11,607	22,633	26,034	10,444	4,359	5,772	12,783
1938	13,157	12,909	8,510	13,558	7,293	6,440	15,412	41,043	46,023	20,004	5,551	7,666	16,495
1939	14,712	16,524	14,845	14,825	9,199	9,698	16,952	42,274	22,680	12,613	3,961	6,479	15,445
1940	14,097	15,484	14,012	13,174	8,179	7,695	12,567	23,237	14,723	7,555	3,721	6,150	11,730
1941	14,911	14,598	11,553	14,048	6,333	5,259	8,670	9,531	9,354	7,985	5,876	11,110	9,954
1942	12,308	15,986	11,806	16,154	8,599	8,063	16,122	27,746	38,160	20,756	6,706	8,135	15,897
1943	15,081	16,793	12,585	17,164	13,043	12,213	39,754	47,810	60,907	34,876	10,270	8,641	24,104
1944	14,850	17,716	15,359	14,391	6,271	5,296	8,961	16,272	17,671	13,051	8,332	14,062	12,700
1945	15,760	15,739	16,246	11,246	5,667	7,090	11,161	24,469	35,320	15,135	4,350	6,958	14,199
1946	8,986	15,689	12,601	14,864	7,538	7,676	17,110	40,680	34,812	17,575	6,231	8,628	16,069
1947	17,608	20,436	12,816	16,903	12,803	17,416	31,497	71,871	47,104	19,130	8,826	10,318	23,947
1948	15,466	17,804	18,083	13,993	13,797	14,476	29,222	73,246	73,886	22,257	12,740	9,237	26,182
1949	13,791	17,147	11,390	15,121	11,050	8,742	17,990	56,840	34,810	12,460	6,106	8,428	17,859
1950	15,964	18,155	14,895	14,593	11,131	15,047	25,326	41,071	74,260	40,041	14,870	10,086	24,650
1951	19,301	16,805	13,571	15,341	13,652	25,629	36,834	69,559	48,691	30,299	11,350	13,125	26,253
1952	19,179	19,419	17,468	13,830	11,824	11,201	25,135	63,263	32,677	16,554	6,835	7,541	20,449
1953	14,459	16,868	12,655	14,849	8,966	9,490	12,983	32,401	67,053	26,088	8,734	7,427	19,342
1954	12,436	16,704	12,812	10,875	10,756	13,169	23,672	59,488	56,357	38,472	12,520	11,007	23,250
1955	17,245	16,410	17,010	13,081	13,837	7,406	12,906	24,302	55,570	31,318	9,436	8,302	18,895
1956	18,128	15,313	11,336	12,105	15,269	19,802	41,463	75,849	59,774	22,595	9,560	9,096	25,855
1957	15,317	18,124	13,948	11,596	12,127	11,723	13,876	60,819	44,857	13,970	5,949	7,326	19,173
1958	15,590	16,864	14,806	11,904	8,095	11,043	10,569	56,363	37,636	14,734	6,012	7,166	17,638
Mean	15,297	16,843	13,947	13,983	10,272	11,197	20,259	43,057	40,623	18,536	7,281	8,641	18,328

Table 37 - Modified Mean Discharge in c.f.s., Clark Fork at Whitehorse Rapids near Cabinet, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										38,850	14,190	10,666	
1929	16,868	19,002	18,002	15,337	8,558	9,649	13,157	33,298	31,187	15,202	6,016	7,573	16,199
1930	18,131	17,972	10,361	14,041	12,872	9,559	28,725	29,898	24,513	11,392	5,426	10,243	16,074
1931	17,791	18,302	17,861	14,921	11,115	11,257	14,260	24,896	12,813	6,926	8,302	16,076	14,563
1932	17,436	17,422	17,124	10,176	11,576	12,771	22,331	51,318	49,730	20,520	7,976	6,996	20,456
1933	9,770	11,838	12,937	14,763	18,053	11,265	25,251	43,815	88,543	29,618	10,330	10,026	23,788
1934	20,607	22,030	29,621	27,756	21,116	39,178	70,318	67,042	29,073	12,980	5,742	7,667	29,465
1935	17,176	20,282	15,613	14,351	13,010	12,438	21,316	42,977	42,350	21,279	8,126	7,267	19,703
1936	14,049	17,207	13,174	13,615	8,969	11,107	26,921	50,971	32,190	10,690	4,790	7,077	17,574
1937	15,837	17,430	10,508	13,271	10,803	10,137	14,872	27,165	26,122	12,244	5,168	6,362	14,165
1938	13,682	13,573	9,339	14,602	9,400	7,142	25,139	48,123	48,237	23,134	6,700	7,954	18,944
1939	15,412	17,235	15,520	15,434	11,347	12,805	23,002	44,772	27,770	15,123	5,365	7,189	17,619
1940	14,664	16,027	14,697	13,772	10,388	10,856	17,943	26,045	17,214	8,832	4,600	6,800	13,492
1941	15,540	15,244	12,378	14,774	8,436	7,844	11,580	12,941	8,457	9,387	6,569	11,838	11,266
1942	13,148	17,278	14,916	18,269	11,145	10,797	20,962	31,816	38,443	23,706	7,616	8,988	18,111
1943	15,893	17,837	13,785	18,399	15,231	12,365	52,041	55,590	66,460	40,386	12,060	9,730	27,483
1944	16,006	18,835	16,646	15,253	8,308	7,544	11,456	18,812	15,365	14,211	9,030	14,807	13,873
1945	16,599	16,541	16,861	12,314	9,558	10,629	13,688	30,189	34,963	17,415	5,739	8,004	16,070
1946	10,113	17,039	14,001	16,519	10,117	8,668	26,106	44,058	40,062	20,325	7,296	9,520	18,673
1947	18,448	21,906	16,196	18,834	15,776	20,145	40,394	75,839	52,634	22,430	10,100	11,449	27,055
1948	16,976	19,224	19,563	15,434	15,912	15,728	37,719	85,466	84,190	25,757	14,090	9,883	29,987
1949	14,879	18,306	12,043	16,196	14,073	10,523	27,425	61,929	40,870	14,840	6,979	8,977	20,604
1950	16,532	18,695	15,814	16,078	14,346	17,812	35,162	49,461	79,043	46,311	16,650	10,819	28,087
1951	20,121	18,905	16,391	17,961	18,192	28,259	46,481	75,197	56,841	35,109	12,720	14,220	30,086
1952	20,369	20,199	19,004	14,946	13,601	11,923	34,071	65,162	37,117	19,114	8,200	8,145	22,679
1953	15,074	17,465	13,235	15,974	12,035	10,156	19,697	39,511	67,797	29,028	10,480	8,056	21,547
1954	12,992	17,271	14,232	11,548	12,746	15,735	32,669	66,167	62,577	43,062	14,510	12,409	26,384
1955	18,568	18,130	18,140	13,896	16,361	8,795	17,481	31,552	60,853	36,158	11,100	9,471	21,700
1956	19,558	17,393	15,196	14,695	17,394	21,834	54,749	84,047	67,694	26,665	11,420	10,175	30,056
1957	16,293	19,011	15,488	12,461	14,735	12,472	22,513	67,237	50,147	16,090	7,542	7,666	21,829
1958	16,446	17,771	16,066	12,649	10,196	12,127	18,631	58,562	40,896	16,965	6,946	7,966	19,660
Mean	16,166	17,846	15,490	15,275	12,846	13,384	27,535	48,129	44,472	21,497	8,586	9,445	20,889

Table 38 - Modified Mean Discharge in c.f.s., Pend Oreille River at Newport, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										41,190	13,930	7,401	
1929	22,877	26,007	26,985	15,517	9,538	11,717	16,536	33,064	24,601	14,792	6,020	7,714	18,008
1930	23,200	23,838	19,434	14,121	14,582	10,789	28,246	28,097	17,703	11,452	5,550	10,134	17,254
1931	22,850	24,418	25,865	15,891	12,615	14,365	19,500	22,913	6,793	7,401	8,376	16,178	16,459
1932	22,654	24,218	25,788	13,165	13,286	18,106	27,276	51,833	59,780	21,000	8,220	7,148	24,376
1933	15,459	20,448	23,607	16,889	19,343	10,122	32,708	39,622	99,343	33,288	10,760	11,208	27,657
1934	27,117	25,682	35,380	35,486	25,446	56,756	66,310	75,593	32,223	13,080	6,340	7,816	34,016
1935	23,408	30,102	26,353	18,029	16,514	14,853	26,556	39,435	50,720	22,659	8,370	7,694	23,728
1936	19,849	23,841	22,025	15,278	9,202	13,575	26,256	51,239	36,340	11,130	5,830	8,008	20,237
1937	21,596	23,997	19,846	13,635	11,773	11,987	21,055	26,444	24,063	13,154	6,183	14,365	17,349
1938	20,094	23,267	21,615	19,630	12,449	8,415	33,496	47,290	56,567	24,184	7,470	16,369	24,244
1939	21,292	24,152	24,971	17,417	12,624	15,925	26,038	38,944	31,770	15,973	5,660	15,575	20,891
1940	20,288	22,872	25,149	15,270	13,321	15,934	25,813	20,237	15,885	9,693	4,890	15,939	17,095
1941	21,712	22,234	21,805	16,958	10,664	11,914	16,655	14,277	3,000	8,129	7,461	17,791	14,408
1942	19,988	25,298	28,936	21,035	12,975	13,474	23,940	23,403	45,423	26,146	8,010	9,345	21,518
1943	21,984	25,703	23,456	19,779	16,575	11,295	53,561	61,282	74,840	43,526	12,460	9,842	31,205
1944	21,736	25,401	25,872	16,220	8,807	8,965	15,176	17,690	7,241	14,841	9,103	15,097	15,547
1945	22,048	23,091	26,028	14,092	11,072	15,521	17,919	21,129	44,003	18,445	5,801	8,767	19,009
1946	16,129	25,159	24,071	18,885	12,027	8,528	33,945	42,228	51,022	22,765	7,940	10,278	22,756
1947	24,557	30,436	21,852	22,184	18,846	26,609	42,672	78,369	61,164	23,850	10,870	12,280	31,182
1948	25,955	22,010	28,987	18,004	18,516	21,808	40,076	91,265	100,790	29,157	15,840	10,789	35,269
1949	20,927	26,097	21,571	17,326	16,775	11,607	34,221	62,219	46,920	15,810	7,604	9,584	24,228
1950	22,602	27,355	26,504	19,124	17,646	20,242	42,008	50,580	94,543	51,401	18,260	11,312	33,481
1951	26,771	23,050	21,644	22,591	24,742	40,879	49,229	76,609	62,071	36,159	13,370	15,040	34,392
1952	28,809	27,787	30,140	17,352	16,614	13,815	39,274	67,040	46,527	21,554	9,086	7,423	27,142
1953	19,799	24,775	22,535	20,646	16,775	8,437	27,176	33,651	77,157	30,638	10,960	7,765	24,993
1954	18,176	25,078	24,174	14,158	15,027	14,735	37,295	66,443	73,257	46,792	14,920	12,533	30,266
1955	22,908	24,303	28,766	14,996	17,377	8,656	23,878	22,043	73,833	41,338	11,080	9,654	24,877
1956	26,447	23,632	19,878	18,495	19,363	31,794	54,973	95,238	78,744	28,535	11,710	10,403	34,943
1957	21,187	26,607	24,714	13,835	16,414	12,052	31,182	66,399	56,767	17,160	7,305	7,527	25,108
1958	21,984	24,251	25,104	14,363	14,524	11,725	29,396	52,970	44,936	17,587	6,626	6,327	22,507
Mean	22,147	24,837	24,769	17,679	15,181	16,487	32,079	47,252	49,934	23,055	9,069	10,997	24,457

Table 39 - Modified Mean Discharge in c.f.s., Pend Oreille River below Z Canyon near Metaline Falls, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										41,790	14,330	11,679	
1929	23,177	26,507	27,215	15,767	9,768	11,977	16,836	32,864	26,601	18,392	7,320	7,995	18,766
1930	23,370	23,968	19,484	14,181	14,642	10,899	27,547	28,797	19,203	13,052	5,950	10,305	17,612
1931	23,030	24,508	25,975	16,001	12,915	14,735	19,700	22,013	8,693	9,001	8,716	16,468	16,839
1932	22,734	24,318	25,888	13,275	13,606	18,906	29,177	53,033	62,980	24,800	9,320	7,548	25,470
1933	15,869	20,748	25,107	18,589	20,763	10,522	34,508	41,122	100,343	39,488	12,860	11,608	29,227
1934	27,307	26,302	35,840	38,436	28,306	59,056	67,216	78,723	35,473	15,580	6,900	8,073	35,676
1935	23,588	30,502	26,913	18,479	17,174	15,673	28,377	40,625	53,270	26,129	9,770	8,086	24,889
1936	20,530	24,633	22,638	15,864	9,407	14,075	26,036	51,659	39,380	13,570	6,030	8,250	21,030
1937	21,769	24,226	20,081	13,991	12,036	12,412	21,446	25,924	25,833	16,164	6,823	7,682	17,383
1938	20,378	23,257	21,785	20,720	13,089	9,835	35,787	49,310	59,677	28,404	8,300	8,896	24,975
1939	21,395	24,327	25,042	17,521	12,614	15,875	26,938	38,894	33,630	*17,153*	*5,970*	*7,863*	*20,639*
1940	20,591	23,171	25,204	15,445	13,679	17,094	28,134	21,347	18,885	10,982	5,038	7,899	17,284
1941	21,930	22,628	22,396	17,338	11,194	13,124	17,705	15,707	5,120	8,958	7,640	14,250	14,861
1942	21,208	26,848	30,796	22,985	14,789	14,094	24,961	25,733	48,933	29,896	9,290	10,416	23,350
1943	22,146	25,933	23,796	19,119	17,765	11,895	55,872	63,102	75,760	48,546	14,680	10,442	32,437
1944	22,456	25,971	26,302	16,815	9,800	9,215	15,556	18,540	8,841	16,471	9,548	15,338	16,271
1945	22,304	23,205	25,732	14,242	12,232	16,391	18,959	24,439	46,223	21,985	6,961	9,166	20,172
1946	16,549	25,669	24,631	19,695	12,777	9,678	37,306	47,338	54,792	26,475	9,160	10,968	24,600
1947	24,687	30,796	22,512	22,964	20,446	28,539	44,863	78,969	64,594	26,870	11,770	13,030	32,539
1948	26,405	24,040	29,837	19,104	19,156	22,958	42,386	92,465	108,290	36,537	18,640	11,632	37,624
1949	21,557	26,307	21,471	16,666	17,825	13,327	37,496	64,669	52,550	18,840	9,054	10,405	25,849
1950	23,381	28,235	27,564	18,754	18,596	22,752	45,018	53,120	95,443	*59,081*	*20,770*	*12,705*	35,482
1951	27,251	25,060	23,114	23,681	27,692	44,269	53,329	78,409	67,441	41,209	15,880	16,145	36,994
1952	29,499	28,907	31,110	18,222	18,254	15,895	42,975	73,160	49,507	23,494	9,580	8,143	29,085
1953	19,729	25,955	24,265	22,036	18,885	10,867	54,426	36,191	82,177	33,638	12,420	7,795	28,967
1954	20,186	26,207	25,484	15,708	16,667	17,045	39,541	68,543	79,377	52,032	15,600	14,229	32,602
1955	23,358	25,643	29,686	15,786	18,510	9,136	27,414	24,353	75,733	44,858	12,430	9,984	26,382
1956	27,857	24,412	21,798	20,525	20,753	33,674	59,219	99,438	84,014	31,065	12,410	10,933	37,182
1957	21,477	27,907	26,154	14,875	18,024	14,032	33,818	67,999	60,787	18,800	8,267	8,428	26,719
1958	23,216	25,621	27,291	15,563	17,444	15,525	33,527	55,190	48,856	20,076	8,368	5,687	24,716
Mean	22,631	25,527	25,504	18,412	16,294	17,783	34,869	49,056	53,080	26,385	10,182	10,346	25,839

Table 40 - Observed Mean Discharge in c.f.s., Coeur d'Alene River near Cataldo, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										735	422	339	
1929	449	563	370	305	276	1,760	4,550	5,560	1,570	617	358	334	1,398
1930	317	238	511	241	1,530	2,240	4,790	2,570	1,520	601	329	278	1,257
1931	334	428	276	495	1,040	3,420	6,560	4,190	919	416	276	318	1,555
1932	322	394	353	762	1,980	4,850	12,100	10,900	3,400	906	462	380	3,062
1933	427	2,460	2,350	1,720	760	2,270	8,820	9,100	6,770	1,280	571	485	3,087
1934	871	2,131	13,230	8,323	4,265	6,490	6,336	2,444	971	516	320	298	3,862
1935	636	1,907	1,857	2,214	2,297	3,004	7,915	9,218	2,721	808	462	330	2,780
1936	324	338	317	550	383	2,026	10,730	6,296	1,742	656	347	321	1,997
1937	285	253	521	269	277	1,393	6,437	8,090	2,327	818	484	362	1,799
1938	281	1,531	2,541	2,721	1,278	3,759	10,730	5,846	1,892	735	407	323	2,671
1939	373	422	666	813	583	2,798	7,883	4,952	1,419	651	331	295	1,767
1940	317	323	1,093	739	1,994	5,624	6,000	3,426	954	427	273	288	1,786
1941	347	535	1,178	1,077	1,097	2,602	2,489	2,683	1,571	588	366	533	1,257
1942	677	1,276	4,232	1,250	1,268	2,005	6,204	3,400	2,452	1,263	509	365	2,076
1943	328	1,714	1,374	1,174	1,009	2,678	12,570	6,524	3,577	1,355	583	388	2,768
1944	384	439	946	434	603	837	3,905	2,863	1,034	453	299	340	1,043
1945	276	387	389	1,996	2,520	2,291	4,338	8,327	2,020	665	376	479	2,003
1946	476	1,476	2,590	2,574	1,072	4,032	9,750	8,880	2,570	854	398	358	2,928
1947	603	2,929	6,492	2,532	3,947	4,384	6,623	5,198	1,972	738	424	423	3,015
1948	1,442	1,682	1,670	2,573	1,677	1,978	8,397	12,750	4,412	1,512	898	502	3,295
1949	491	782	676	453	1,578	3,577	10,490	10,500	2,088	731	449	404	2,686
1950	489	1,616	1,687	2,312	3,198	5,988	8,396	11,600	6,687	1,906	733	485	3,757
1951	1,055	2,087	4,677	2,582	6,652	2,306	7,297	6,569	2,196	886	460	382	3,068
1952	1,446	1,916	2,440	863	1,707	1,520	10,360	6,905	2,017	952	471	388	2,575
1953	320	310	341	3,386	4,395	2,183	5,846	7,017	3,483	1,023	504	360	2,414
1954	337	518	1,840	1,721	3,166	3,402	8,241	10,870	3,896	1,416	735	603	3,058
1955	658	1,441	955	719	1,374	810	4,193	9,704	4,721	1,562	664	521	2,279
1956	1,278	3,006	5,559	2,731	1,228	2,752	12,430	10,560	3,034	1,126	606	429	3,731
1957	639	639	2,406	832	1,545	3,666	8,142	11,940	2,400	925	552	406	2,851
1958	436	588	1,015	1,268	4,131	2,770	7,026	6,920	1,545	669	379	360	2,242
Mean	554	1,144	2,152	1,654	1,961	2,981	7,652	7,193	2,596	902	468	391	2,471

Table 41 - Modified Mean Discharge in c.f.s., Spokane River at Spokane, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										2,476	1,766	1,596	
1929	1,686	1,756	1,746	1,556	1,486	2,046	7,156	13,496	5,726	1,866	1,536	1,716	3,491
1930	1,476	1,456	1,356	1,586	2,646	4,026	11,296	7,506	4,396	1,516	1,436	1,416	3,334
1931	1,386	1,346	1,336	1,336	2,056	6,606	13,896	11,496	2,616	1,356	1,366	1,386	3,853
1932	1,366	1,226	1,226	2,656	2,496	11,596	23,796	29,796	14,096	2,596	1,506	1,436	7,820
1933	1,556	5,686	5,216	5,036	3,016	5,666	14,096	22,896	21,796	4,436	1,596	1,526	7,715
1934	3,033	7,191	22,906	25,426	14,306	12,956	20,926	9,953	3,069	1,662	1,476	1,427	10,353
1935	1,410	4,267	4,671	5,686	6,605	8,080	14,066	22,996	11,196	2,408	1,741	1,954	7,085
1936	1,731	1,257	1,311	2,023	2,525	5,787	16,426	22,636	6,444	1,928	1,727	1,836	5,474
1937	1,934	1,370	1,349	1,746	1,571	2,710	11,916	19,796	8,347	2,133	1,524	1,832	4,698
1938	1,490	2,404	5,660	7,641	4,950	9,642	18,886	19,826	8,026	2,020	1,530	1,662	6,986
1939	1,794	1,788	1,601	2,136	2,961	5,138	16,356	16,626	3,995	1,972	1,926	1,779	4,842
1940	1,529	1,147	1,641	2,306	5,248	13,066	15,136	10,826	3,112	1,675	1,502	1,494	4,885
1941	1,580	1,794	3,808	4,776	4,278	4,872	4,257	6,911	4,613	1,553	1,513	1,657	3,465
1942	2,119	3,568	9,648	4,299	5,171	5,135	12,456	9,131	6,139	2,954	1,208	1,240	5,250
1943	1,491	4,056	4,746	4,441	4,311	4,982	25,026	19,096	14,216	3,473	1,573	1,510	7,394
1944	1,847	2,226	3,308	2,641	2,930	2,508	6,839	6,022	2,880	1,445	1,517	1,522	2,970
1945	1,731	1,877	1,750	3,197	5,337	6,749	9,316	18,426	6,963	2,668	1,015	1,374	5,033
1946	1,841	3,387	5,322	8,291	4,493	8,435	17,466	22,876	9,723	2,572	1,055	1,186	7,235
1947	1,687	4,678	13,086	7,187	9,883	9,781	13,896	16,196	5,976	2,838	1,130	1,512	7,309
1948	3,345	4,091	5,826	9,045	5,485	7,017	15,116	29,076	22,736	3,326	2,412	1,515	9,083
1949	2,144	2,112	3,685	3,440	3,742	11,086	20,086	28,586	8,267	2,064	1,358	1,003	7,321
1950	1,520	3,234	3,930	4,903	6,842	17,486	20,666	25,246	24,276	7,702	2,021	1,276	9,924
1951	2,748	4,981	9,677	8,779	16,416	8,307	15,996	17,526	6,836	2,298	1,031	1,152	7,918
1952	3,417	4,295	6,002	5,114	5,904	4,786	18,216	23,266	6,894	2,715	1,202	1,829	6,967
1953	1,930	2,223	2,404	6,425	11,596	6,421	9,160	19,326	13,566	2,094	1,257	1,665	6,462
1954	2,383	2,418	3,826	4,537	7,244	9,641	14,366	23,916	15,106	3,483	1,935	1,769	7,545
1955	3,392	4,226	3,897	2,758	3,191	2,915	9,283	19,996	17,556	3,891	1,561	1,594	6,191
1956	3,523	6,138	12,356	10,946	5,594	7,258	23,806	29,386	15,096	2,845	1,708	1,845	10,048
1957	3,026	3,582	4,161	4,151	2,790	9,764	16,086	28,056	12,586	2,273	1,345	1,340	7,458
1958	2,533	2,977	3,135	3,420	8,891	9,116	15,056	20,286	6,797	1,983	998	1,530	6,371
Mean	2,088	3,092	5,020	5,249	5,465	7,453	15,035	19,039	9,768	2,592	1,490	1,533	6,485

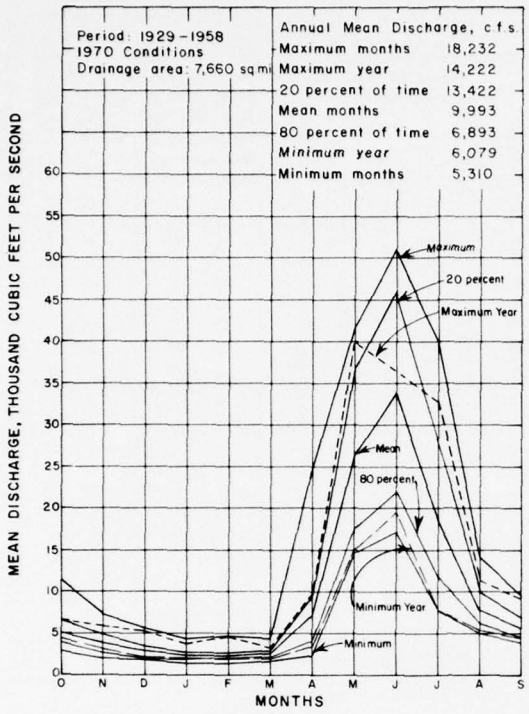


Figure 30 Monthly discharge, Kootenay River at Newgate, B.C.

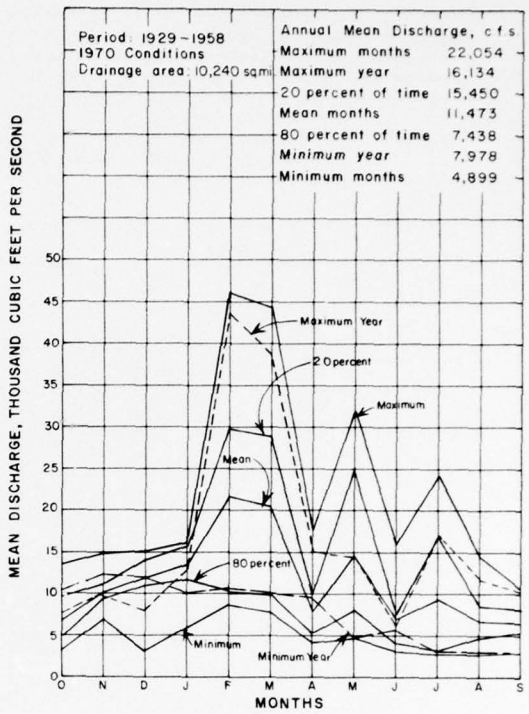


Figure 31 Monthly discharge, Kootenai River at Libby, Montana

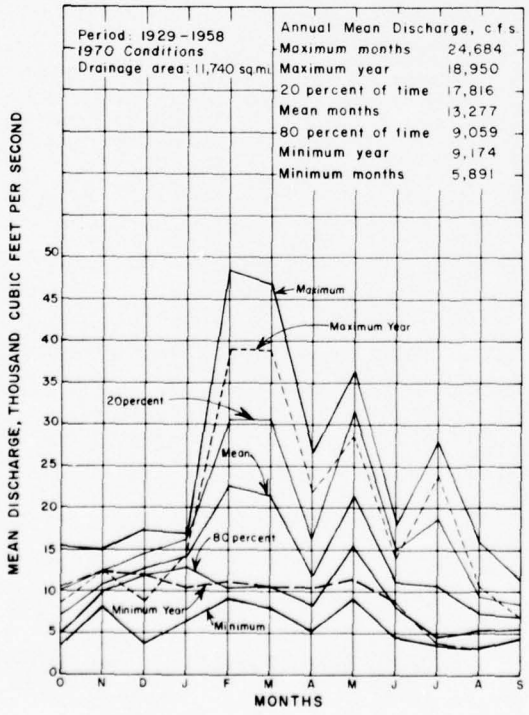


Figure 32 Monthly discharge, Kootenai River at Leonia, Idaho

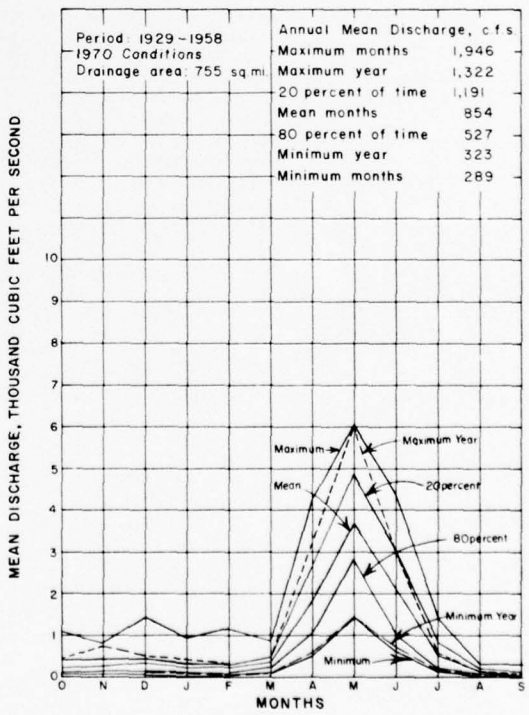


Figure 33 Monthly discharge, Moyie River at Eileen, Idaho

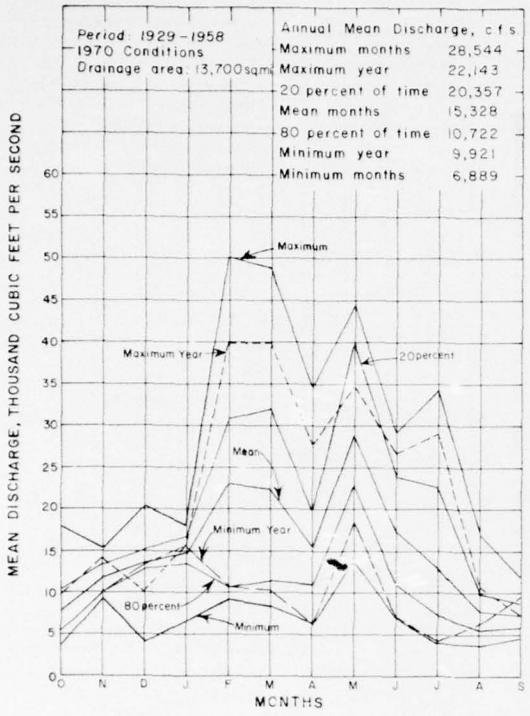


Figure 34 Monthly discharge, Kootenai River at Porthill, Idaho

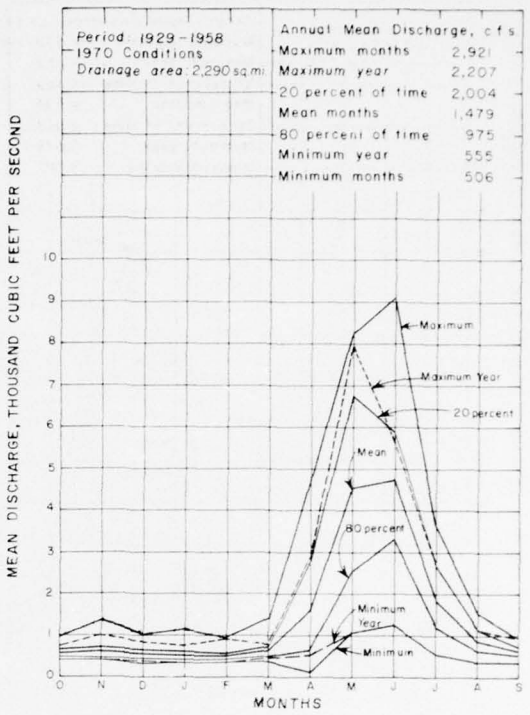


Figure 35 Monthly discharge, Blackfoot River near Bonner, Montana

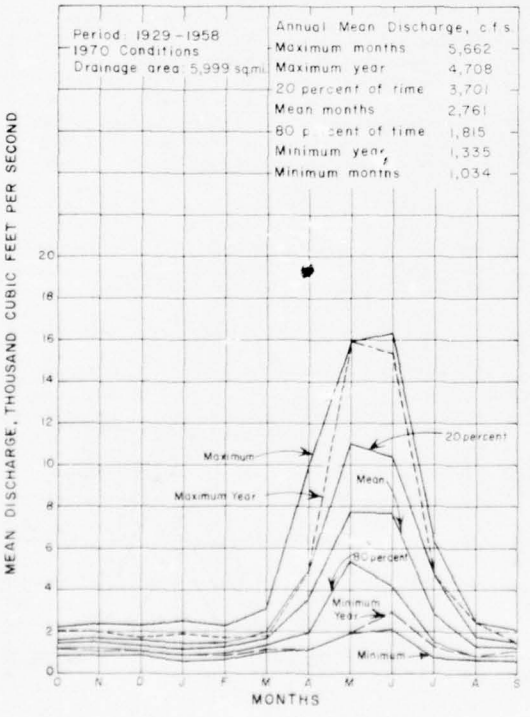


Figure 36 Monthly discharge, Clark Fork above Missoula, Montana

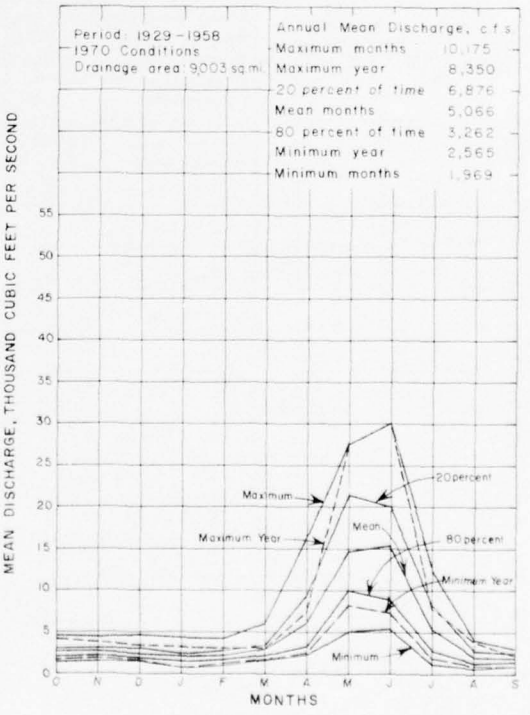


Figure 37 Monthly discharge, Clark Fork below Missoula, Montana

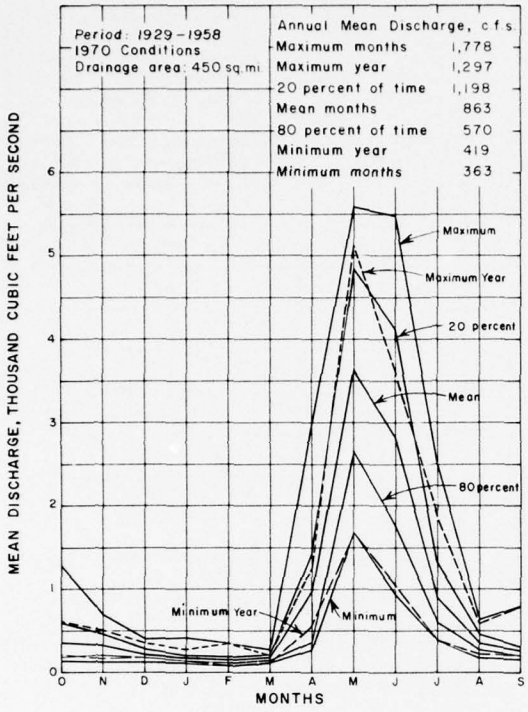


Figure 38 Monthly discharge, Flathead River at Flathead, B.C.

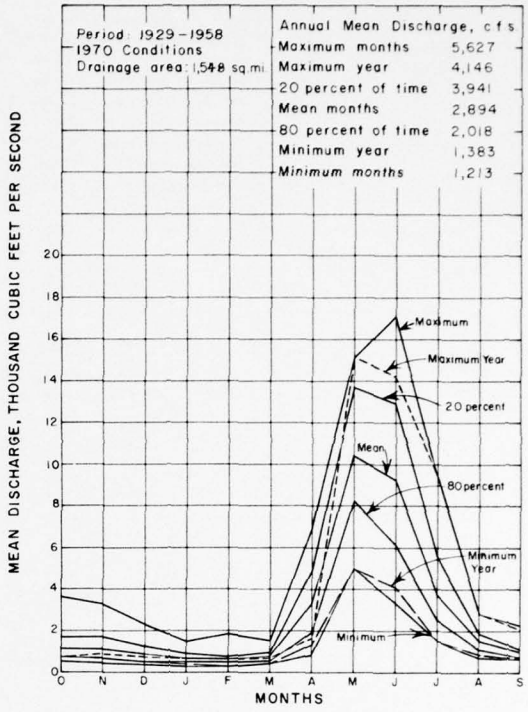


Figure 39 Monthly discharge, Flathead River near Columbia Falls, Montana

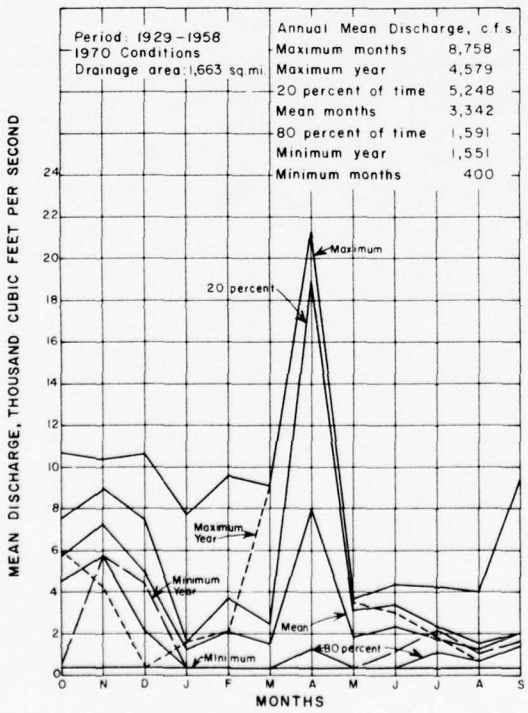


Figure 40 Monthly discharge, S.F. Flathead River near Columbia Falls, Montana

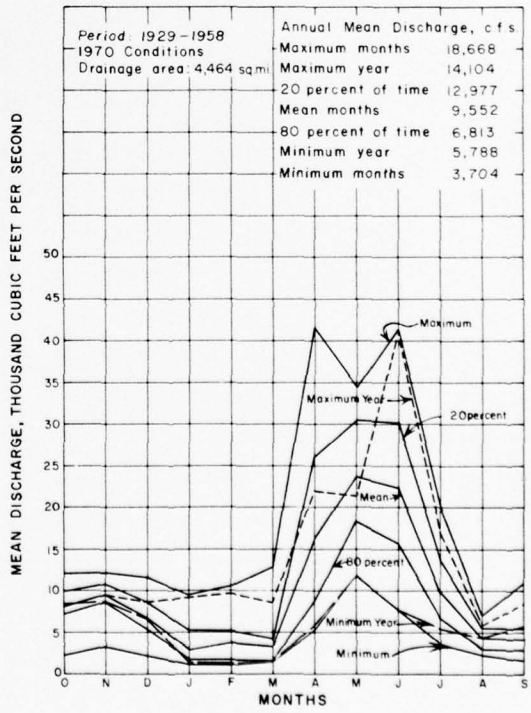


Figure 41 Monthly discharge, Flathead River at Columbia Falls, Montana

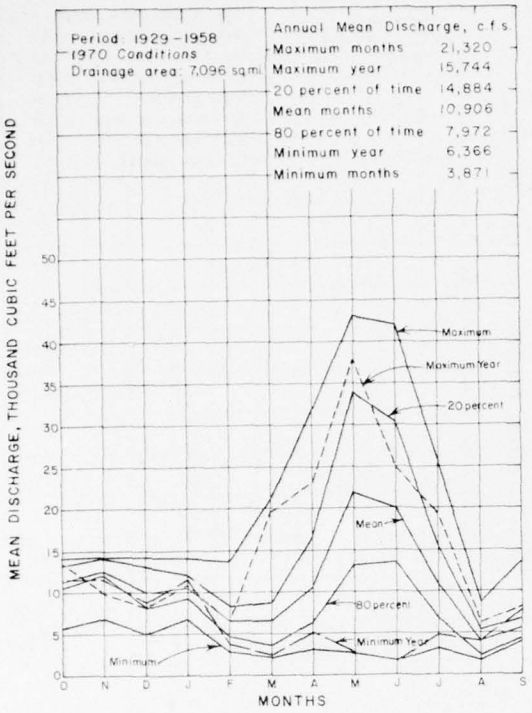


Figure 42 Monthly discharge, Flathead River near Polson, Montana

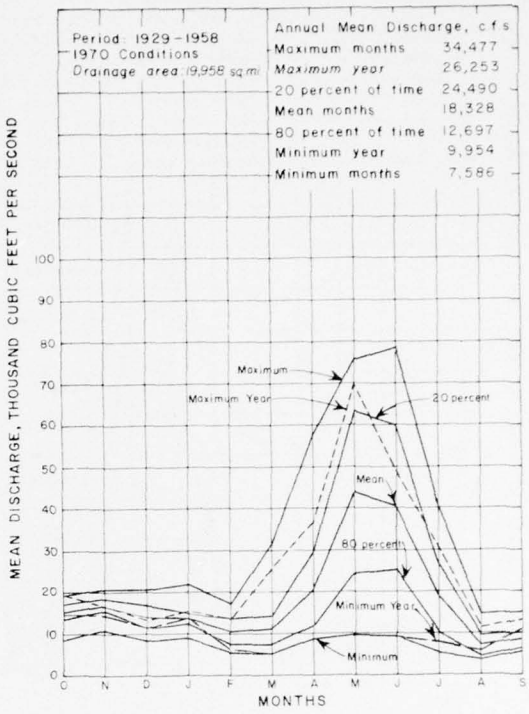


Figure 43 Monthly discharge, Clark Fork near Plains, Montana

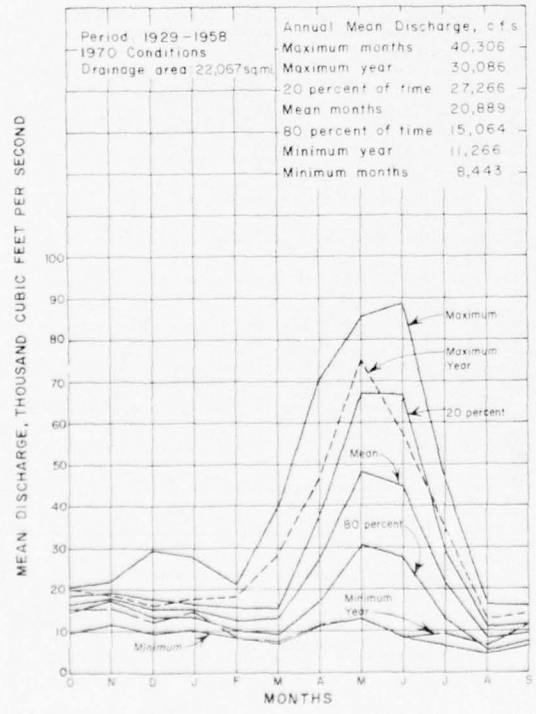


Figure 44 Monthly discharge, Clark Fork at Whitehorse Rapids near Cabinet, Idaho

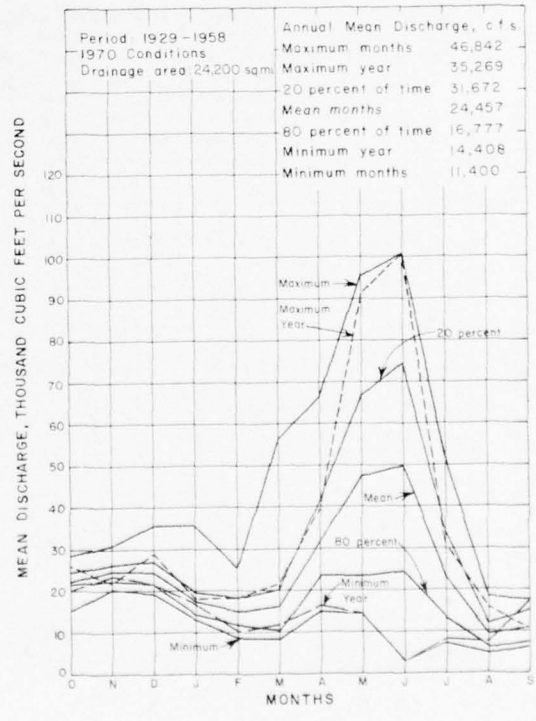


Figure 45 Monthly discharge, Pend Oreille River at Newport, Washington

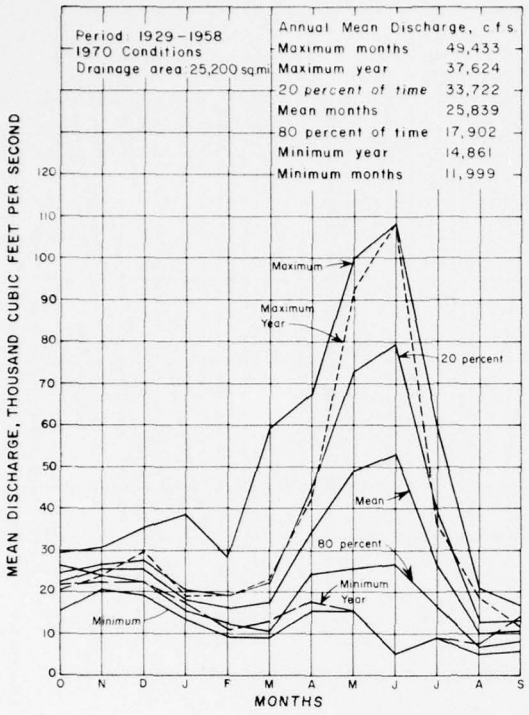


Figure 46 Monthly discharge, Pend Oreille River below Z Canyon near Metaline Falls, Washington

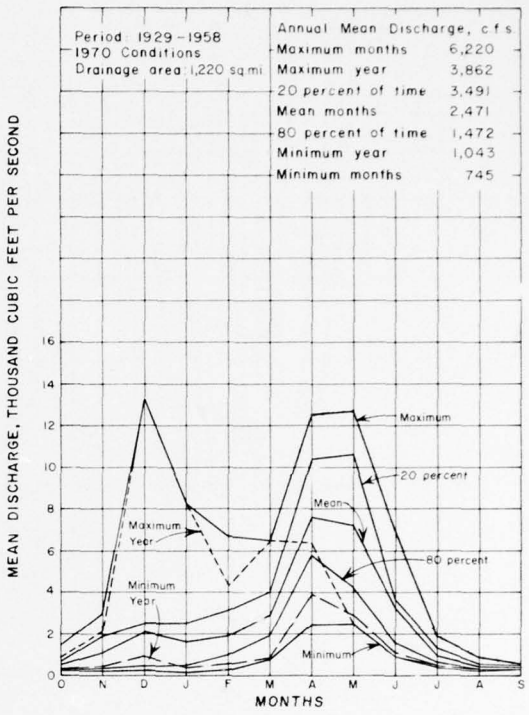


Figure 47 Monthly discharge, Coeur d'Alene River near Cataldo, Idaho

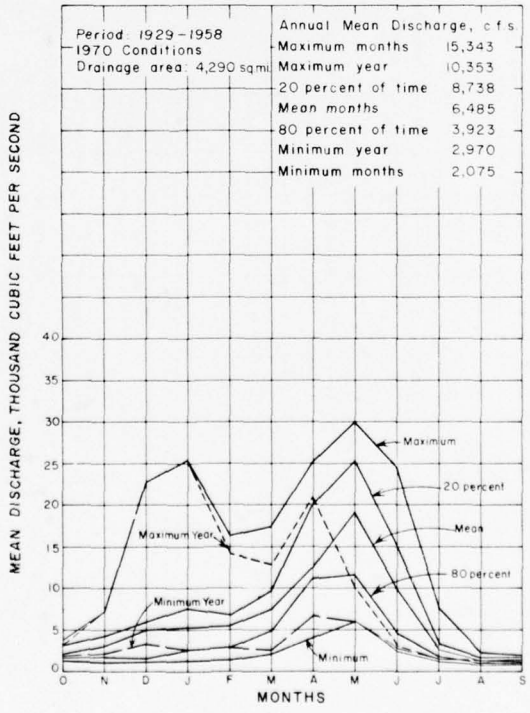


Figure 48 Monthly discharge, Spokane River at Spokane, Washington

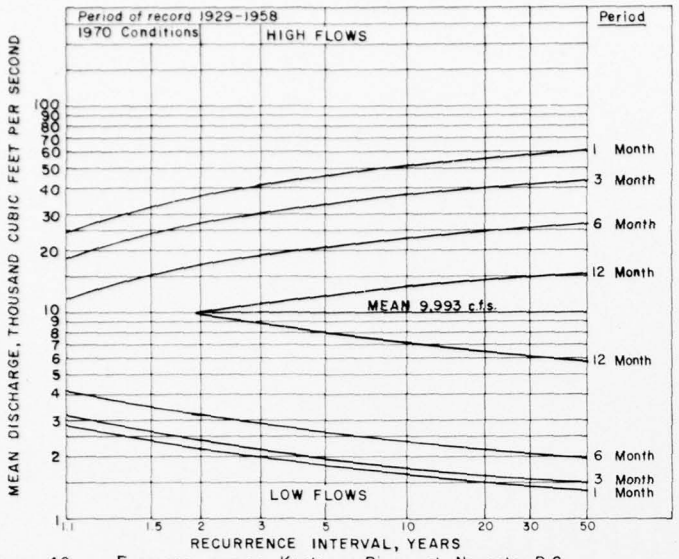


Figure 49 Frequency curves, Kootenay River at Newgate, B.C.

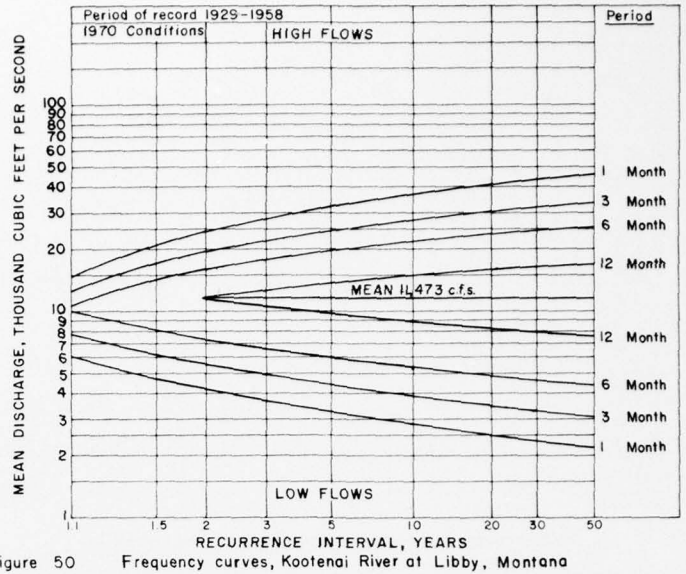


Figure 50 Frequency curves, Kootenai River at Libby, Montana

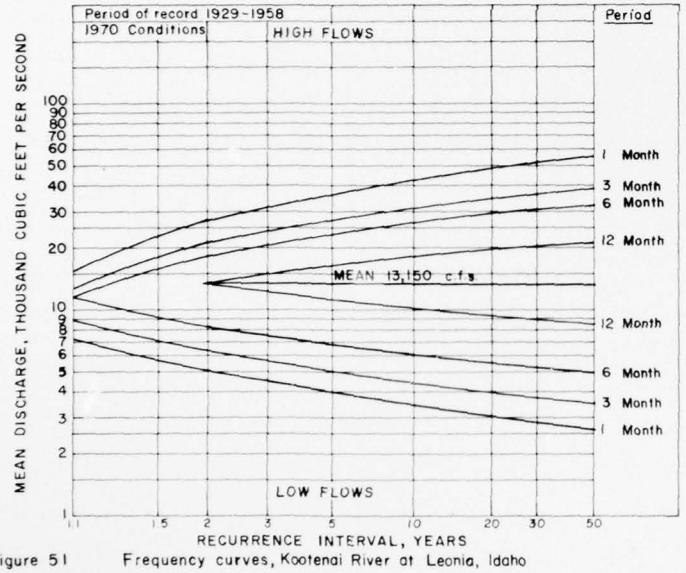


Figure 51 Frequency curves, Kootenai River at Leonia, Idaho

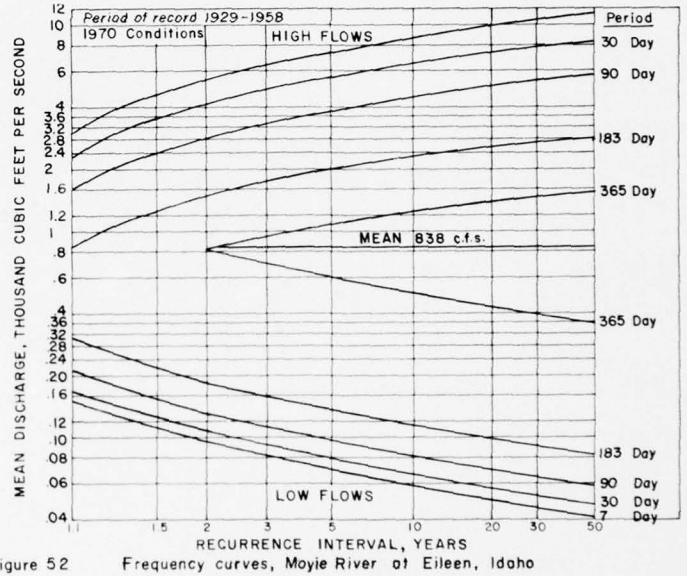


Figure 52 Frequency curves, Moyie River at Eileen, Idaho

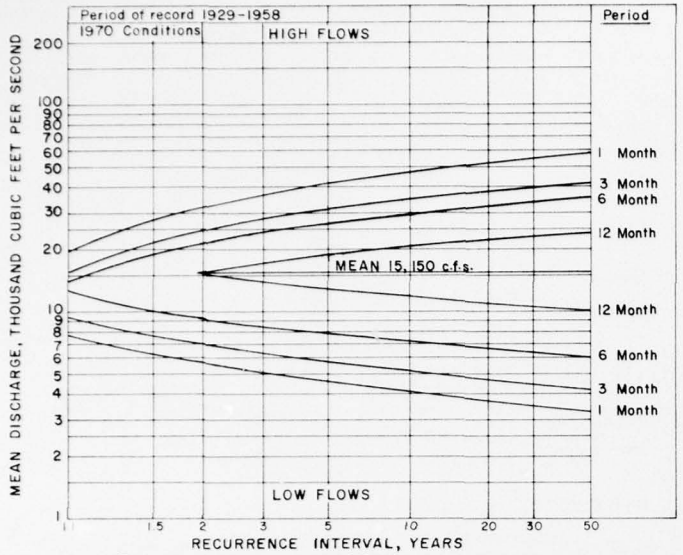


Figure 53 Frequency curves, Kootenai River at Porthill, Idaho

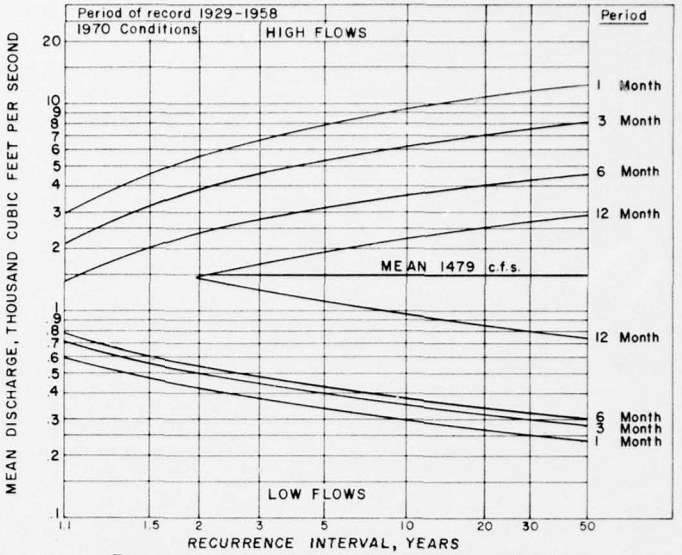


Figure 54 Frequency curves, Blackfoot River near Bonner, Mont.

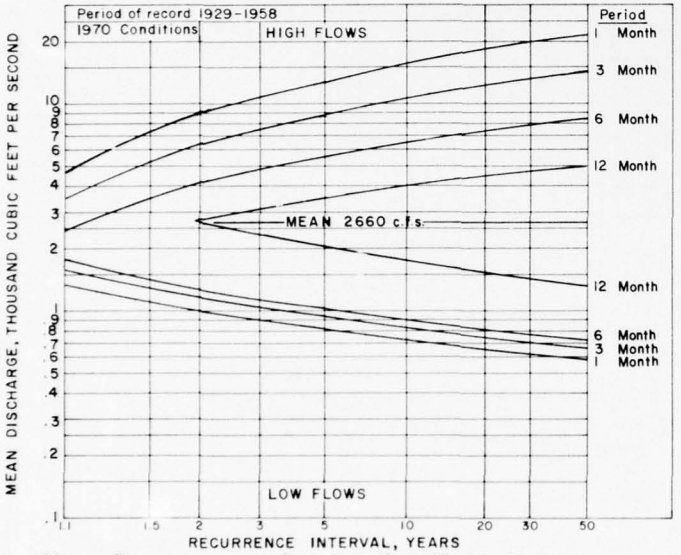


Figure 55 Frequency curves, Clark Fork above Missoula, Montana

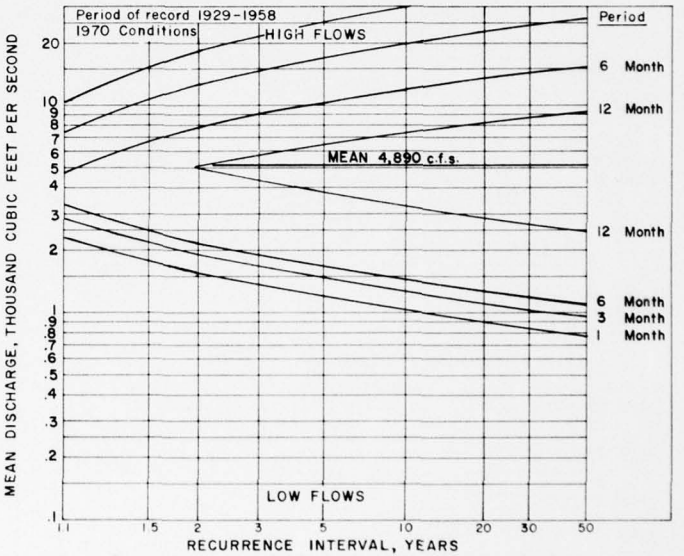


Figure 56 Frequency curves, Clark Fork below Missoula, Montana

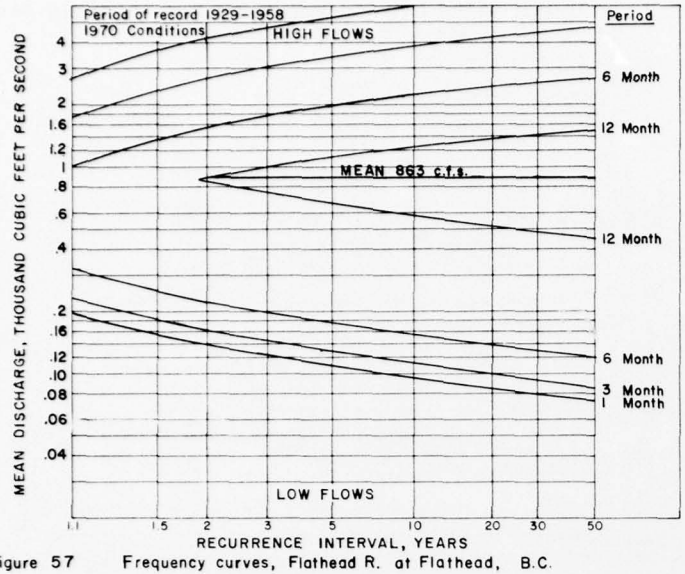


Figure 57 Frequency curves, Flathead R. at Flathead, B.C.

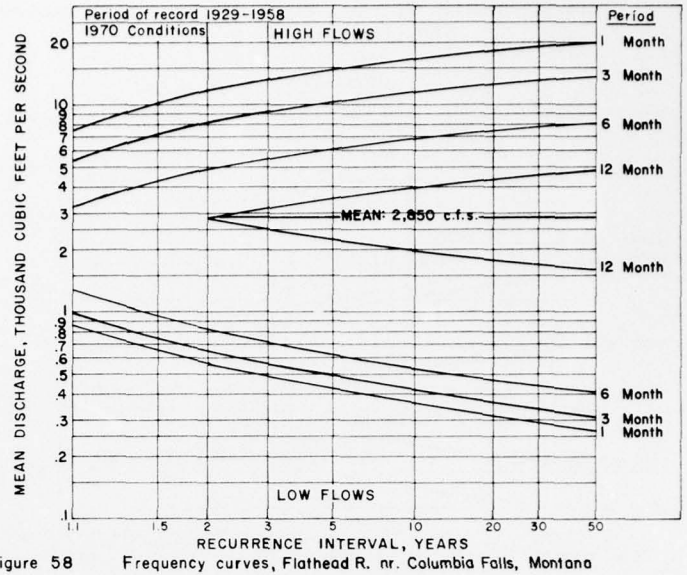


Figure 58 Frequency curves, Flathead R. nr. Columbia Falls, Montana

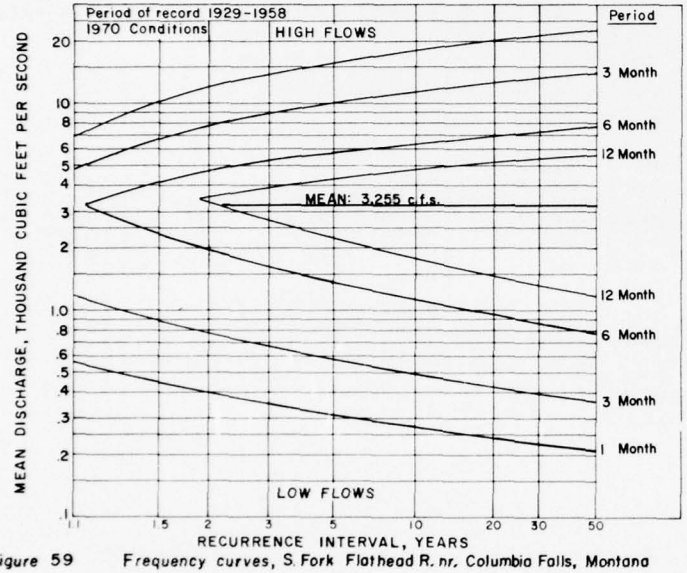


Figure 59 Frequency curves, S. Fork Flathead R. nr. Columbia Falls, Montana

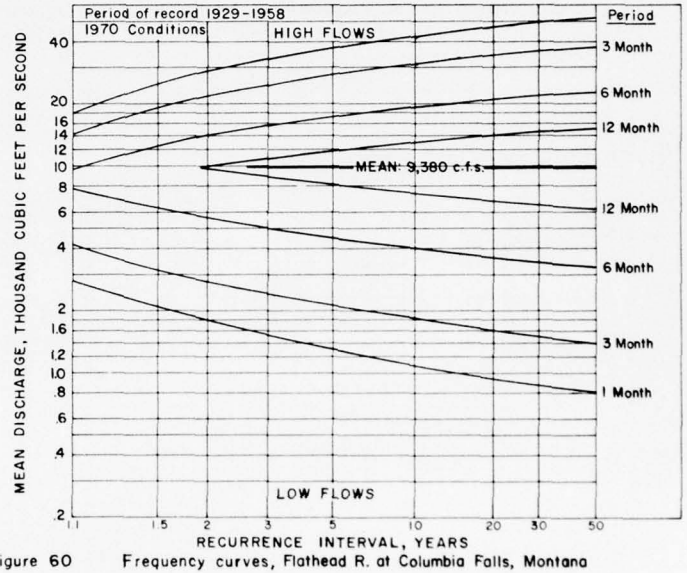


Figure 60 Frequency curves, Flathead R. at Columbia Falls, Montana

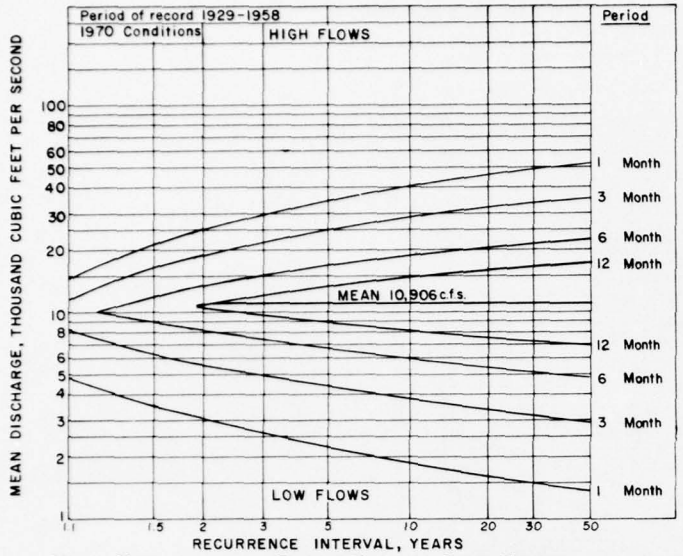


Figure 61 Frequency curves, Flathead River near Polson, Montana

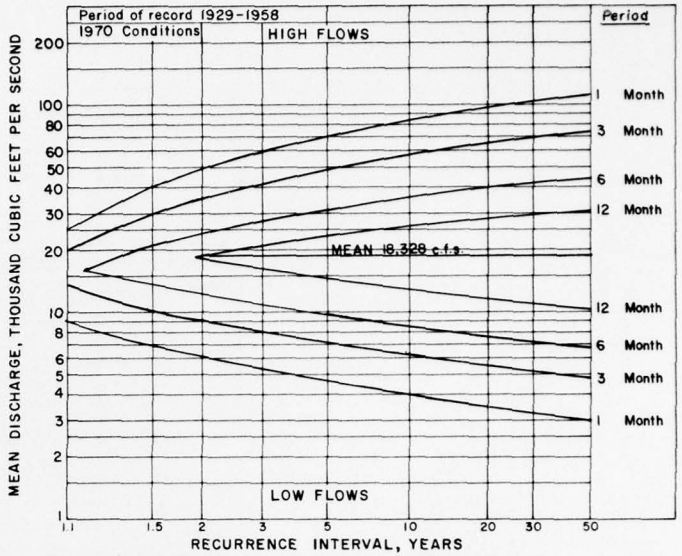


Figure 62 Frequency curves, Clark Fork near Plains, Montana

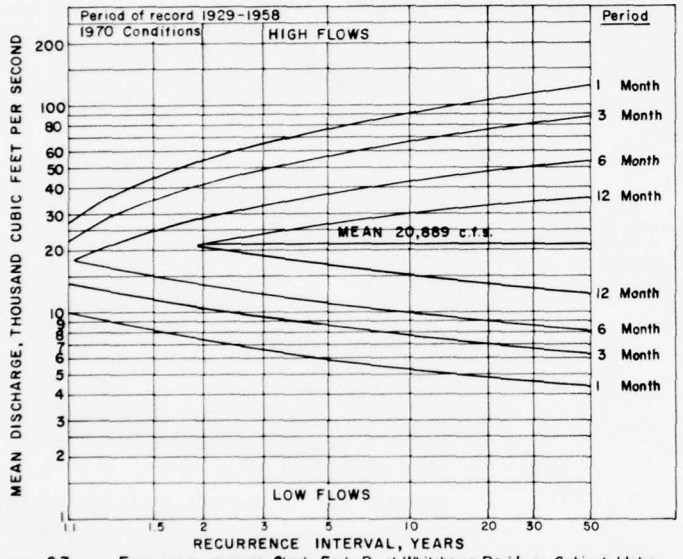


Figure 63 Frequency curves, Clark Fork R. at Whitehorse Rapids nr. Cabinet, Idaho

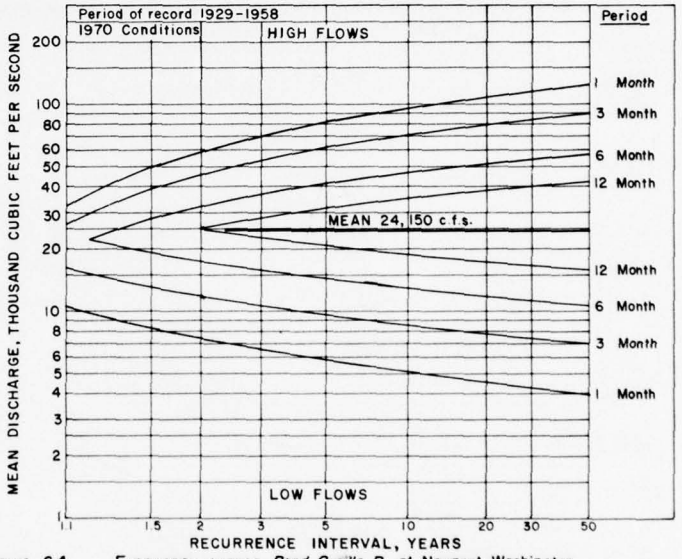


Figure 64 Frequency curves, Pend Oreille R. at Newport, Washington

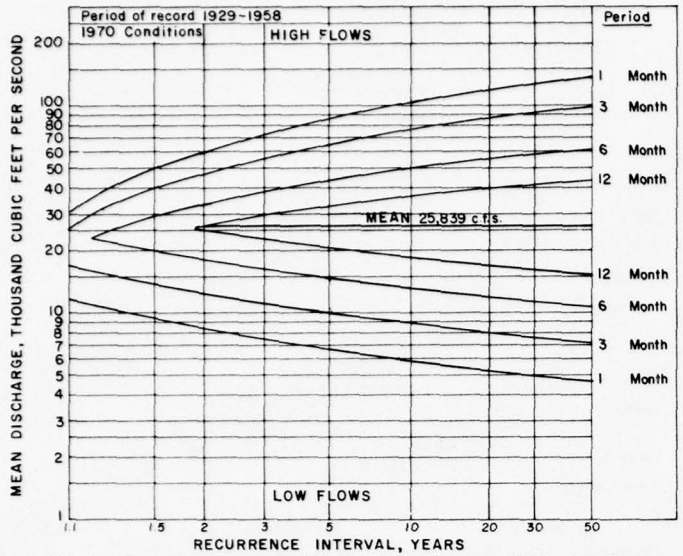


Figure 65 Frequency curves, Pend Oreille R. below Z Canyon, nr. Metaline Falls, Mont.

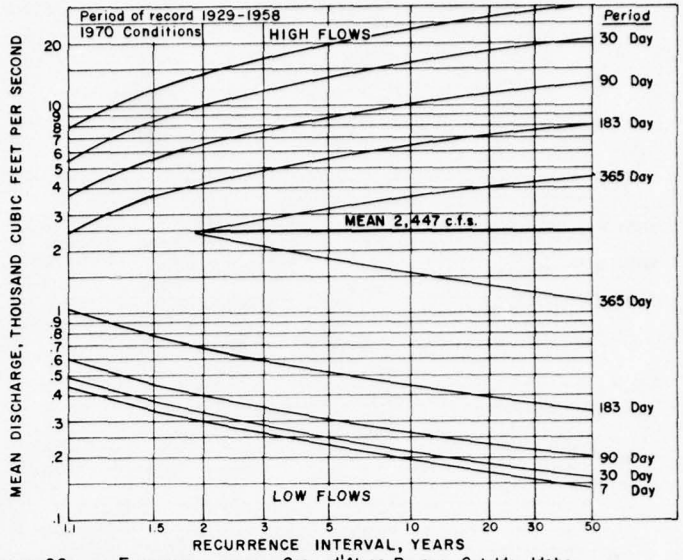


Figure 66 Frequency curves, Coeur d'Alene R. near Cataldo, Idaho

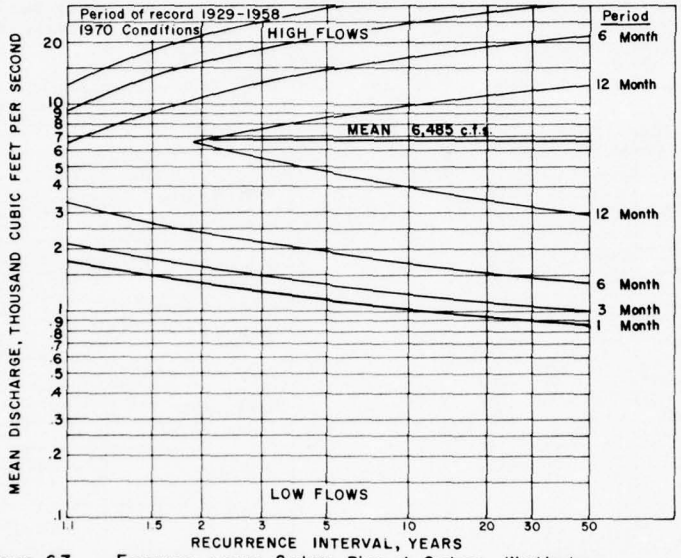


Figure 67 Frequency curves, Spokane River at Spokane, Washington

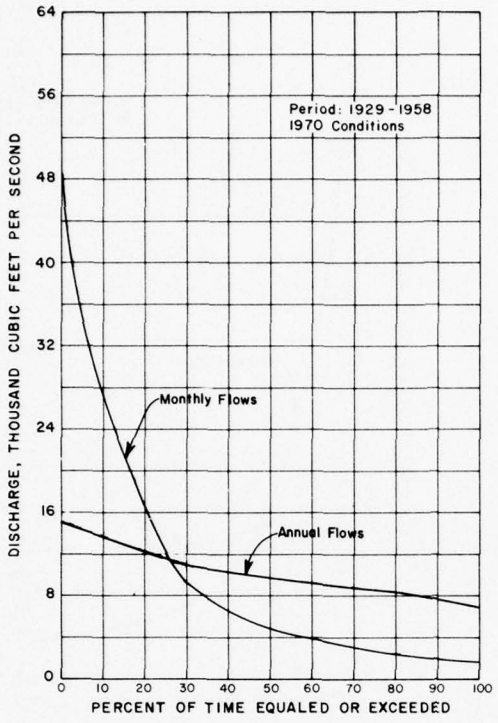


Figure 68 Duration curves, Kootenay River at Newgate, B.C.

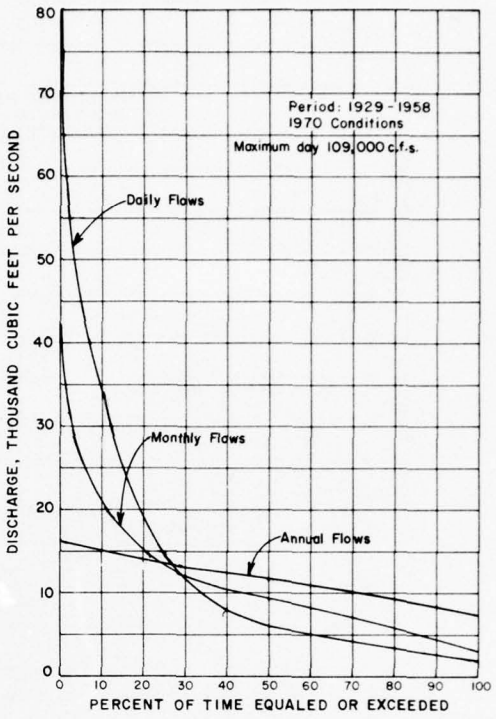


Figure 69 Duration curves, Kootenai River at Libby, Montana

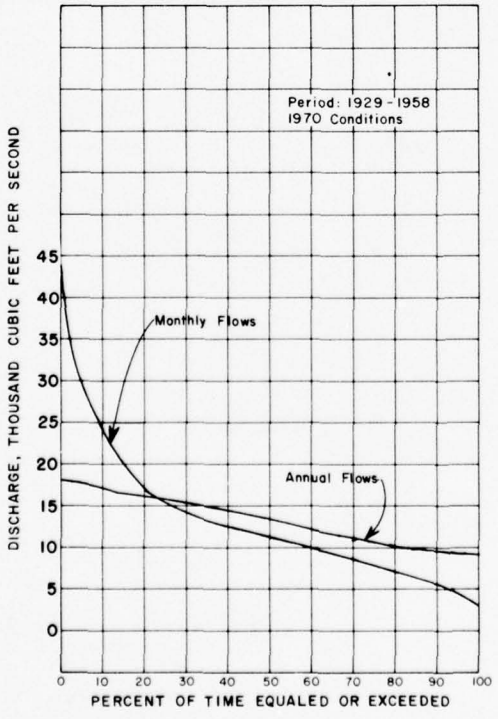


Figure 70 Duration curves, KootenaiRiver at Leonia, Idaho

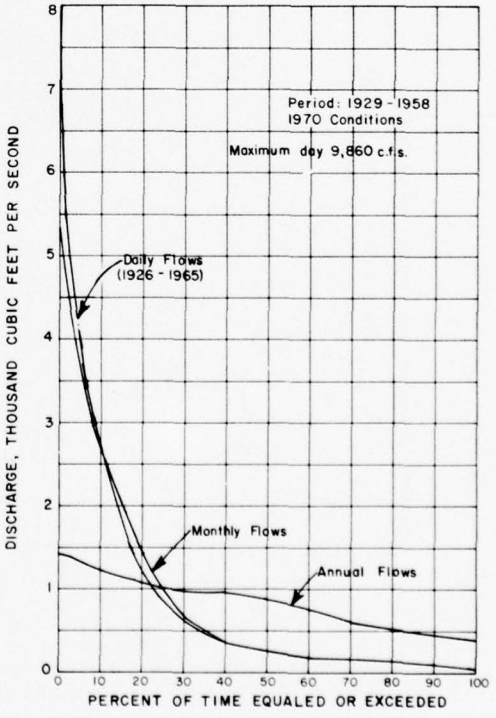


Figure 71 Duration curves, Moyie River at Eileen, Idaho

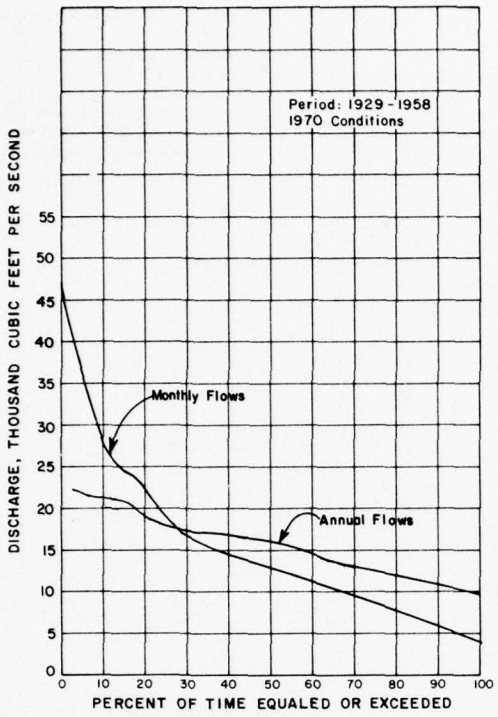


Figure 72 Duration curves, Kootenai River at Porthill, Idaho.

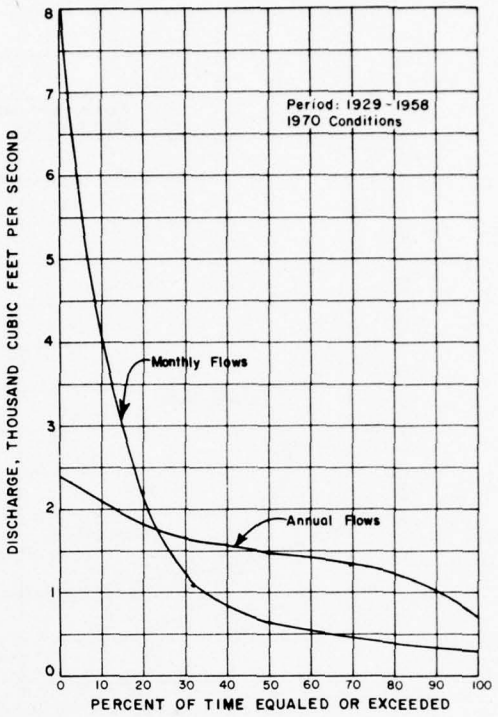


Figure 73 Duration curves, Blackfoot R. nr. Bonner, Mont.

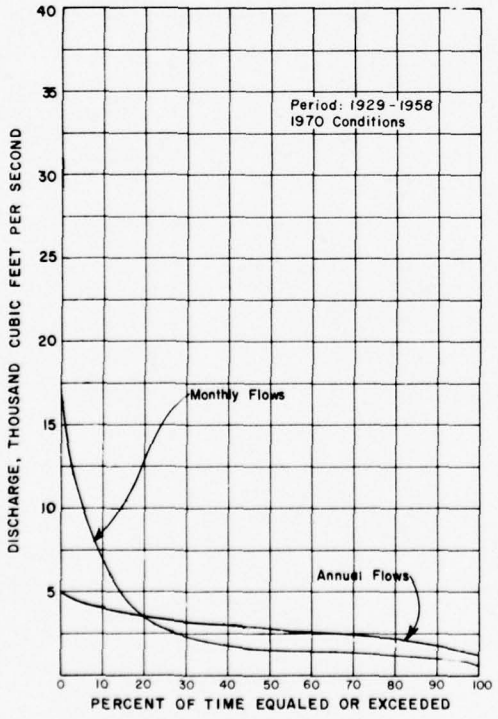


Figure 74 Duration curves, Clark Fork above Missoula, Montana

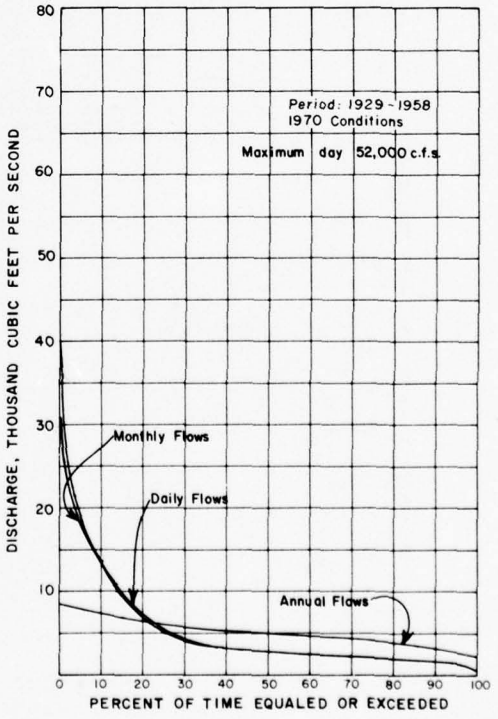


Figure 75 Duration curves, Clark Fork below Missoula, Montana

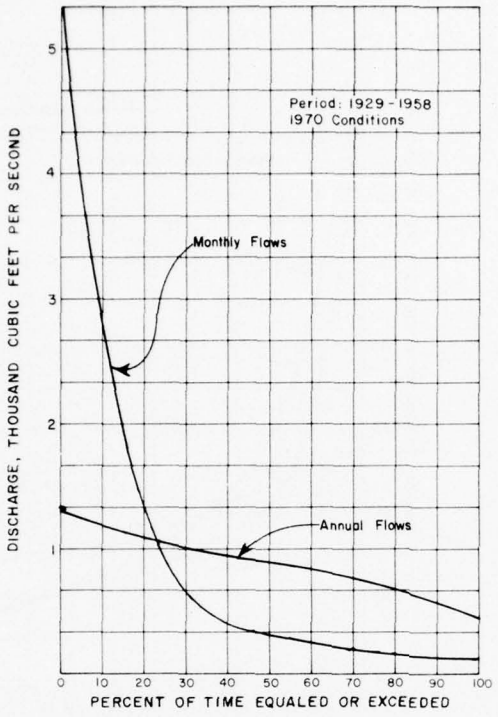


Figure 76 Duration curves, Flathead R. at Flathead, B.C.

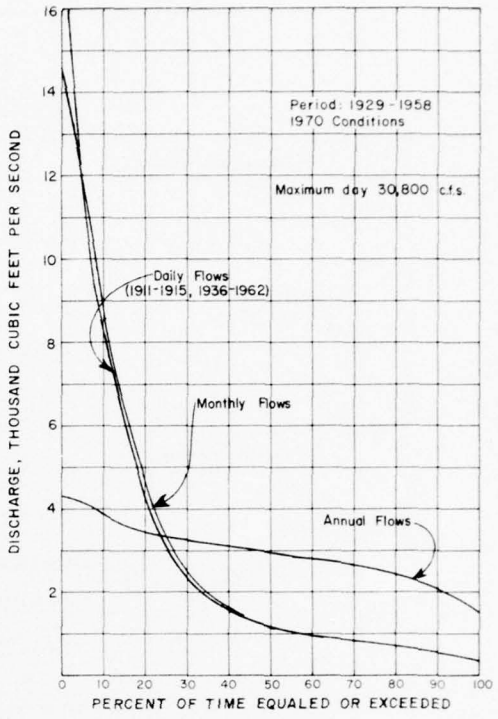


Figure 77 Duration curves, Flathead River nr. Columbia Falls, Mont.

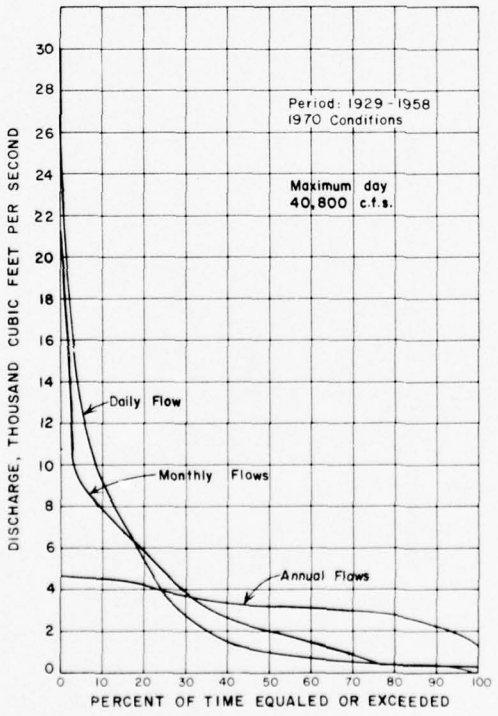


Figure 78 Duration curves, S.F. Flathead R near Columbia Falls, Mont.

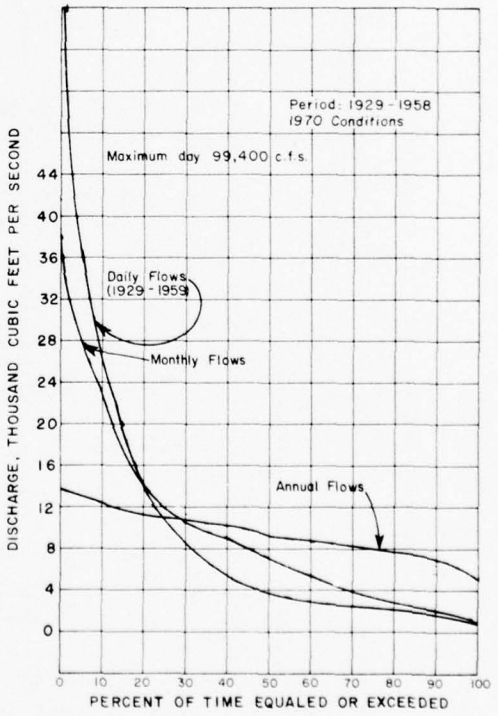


Figure 79 Duration curves, Flathead R. at Columbia Falls, Mont.

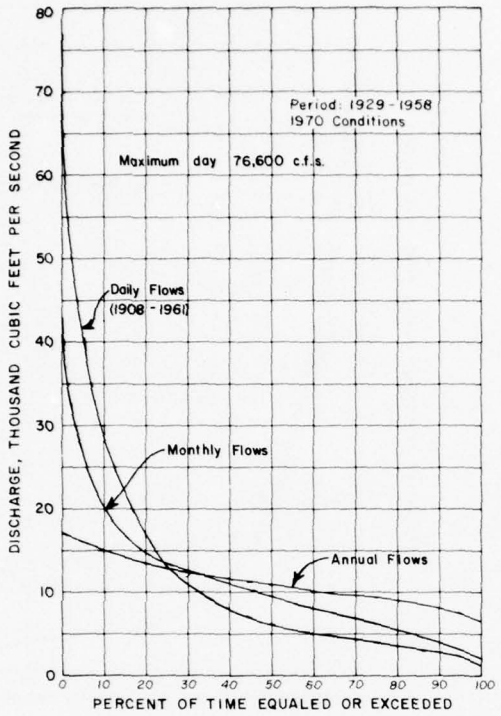


Figure 80 Duration curves, Flathead R. nr Polson, Mont.

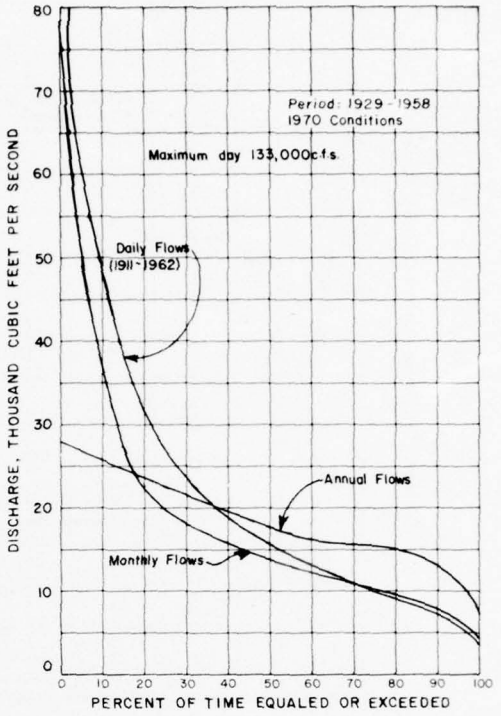


Figure 81 Duration curves, Clark Fork nr. Plains, Mont.

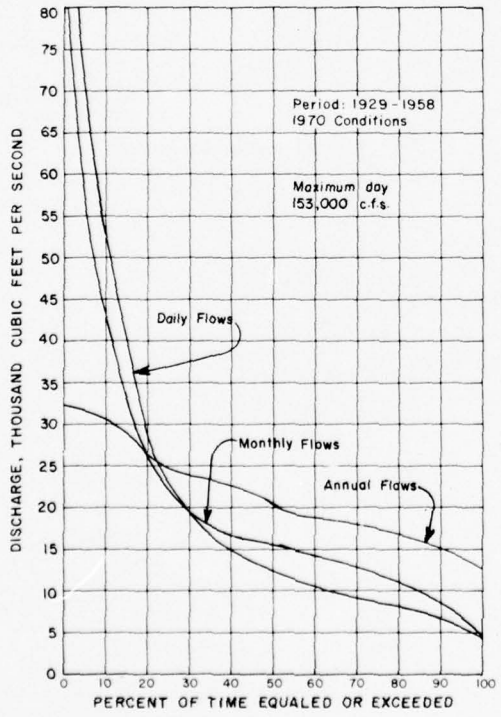


Figure 82 Duration curves, Clark Fork at Whitehorse Rapids near Cabinet, Idaho

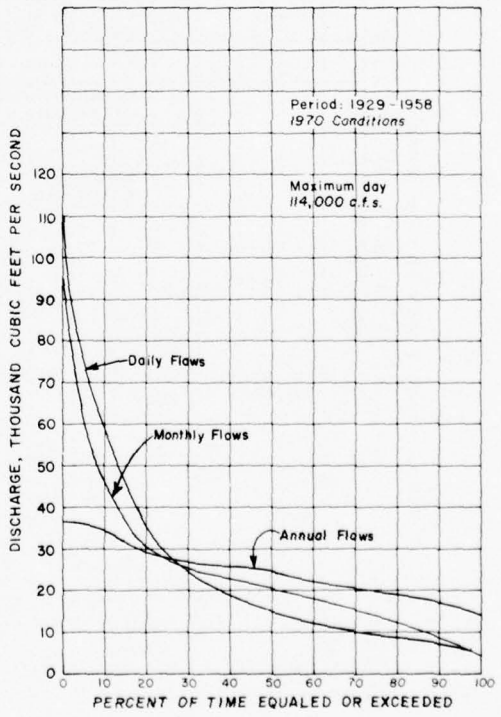


Figure 83 Duration curves, Pend Oreille River at Newport, Washington

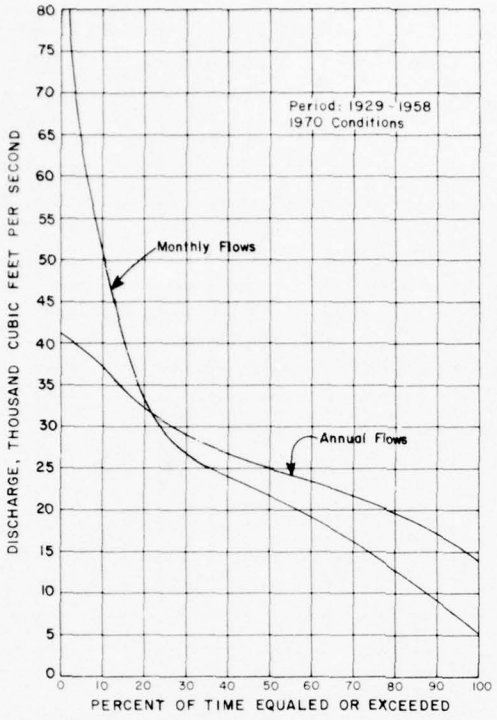


Figure 84 Duration curves, Pend Oreille R. below Z Canyon near Metaline Falls, Washington

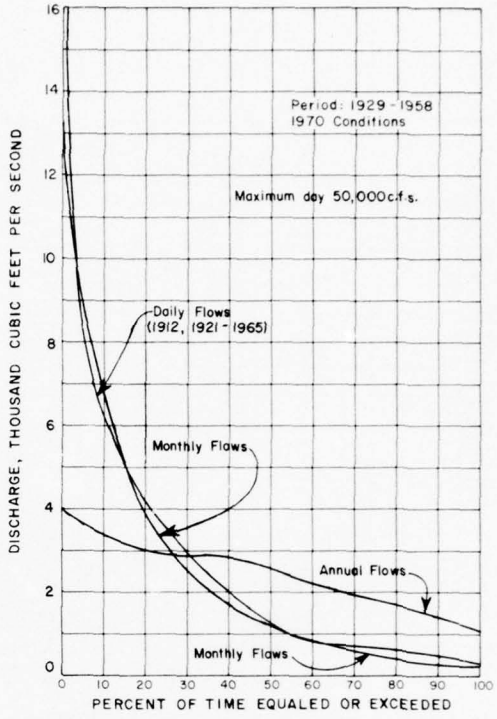


Figure 85 Duration curves, Coeur d' Alene River near Cataldo, Idaho

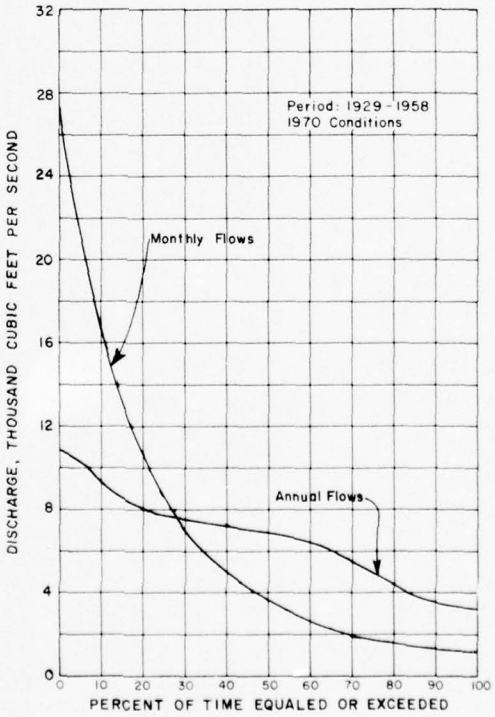


Figure 86 Duration curves, Spokane River at Spokane, Washington

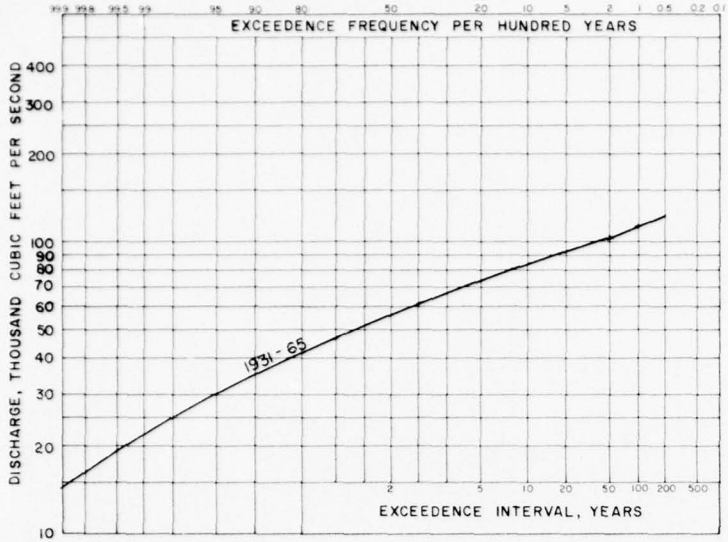


Figure 87 Frequency curve of annual peak flows, Kootenay R. at Newgate, B.C.

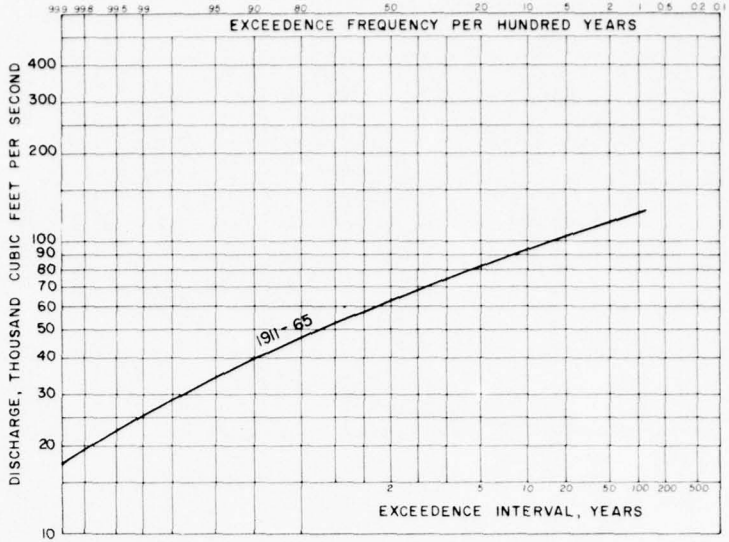


Figure 88 Frequency curve of annual peak flows, Kootenai R. at Libby, Mont.

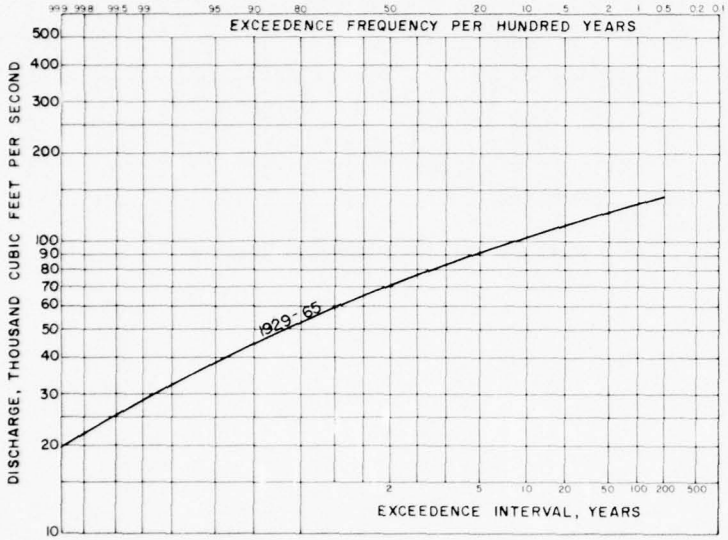


Figure 89 Frequency curve of annual peak flows, Kootenai R. at Leonia, Idaho

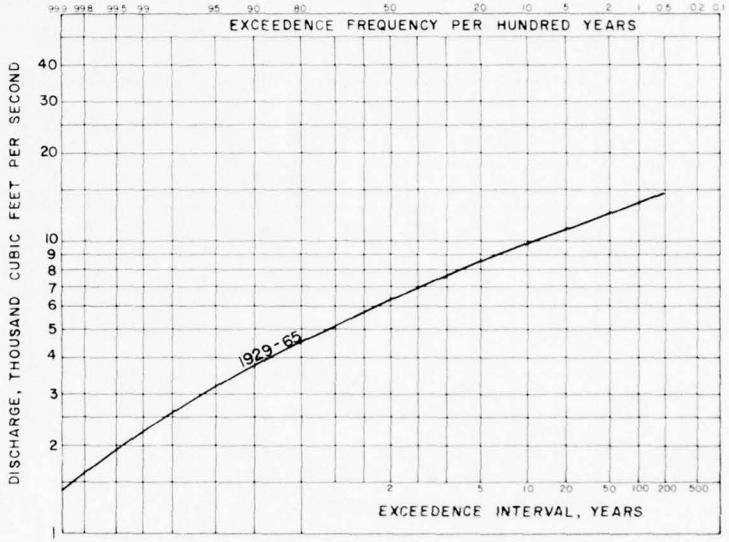


Figure 90 Frequency curve of annual peak flows, Moyie R. nr. Eileen, Idaho

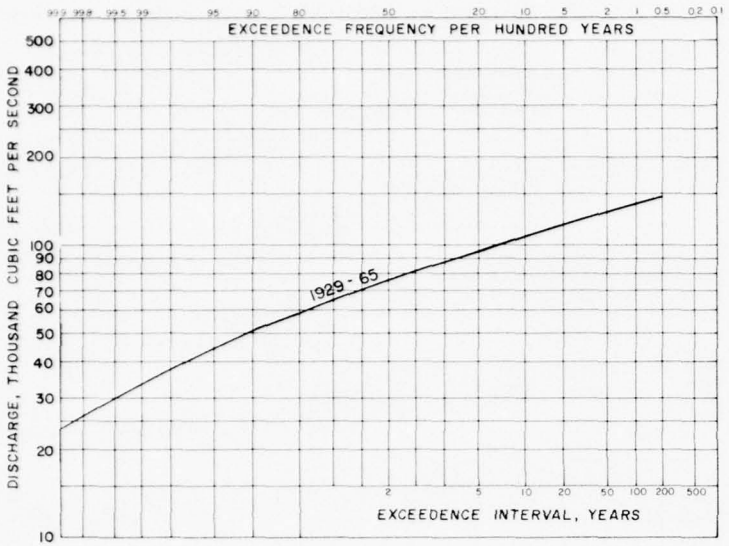


Figure 91 Frequency curve of annual peak flows, Kootenai R. at Porthill, Idaho

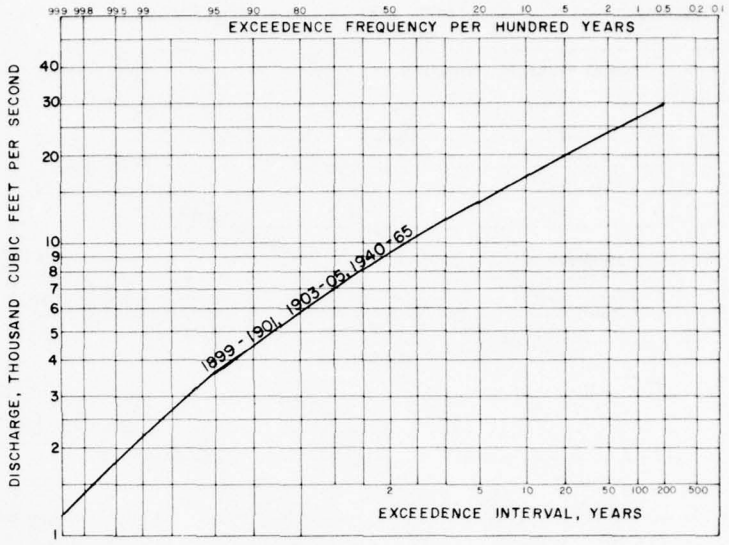


Figure 92 Frequency curve of annual peak flows, Blackfoot R. nr. Bonner, Mont.

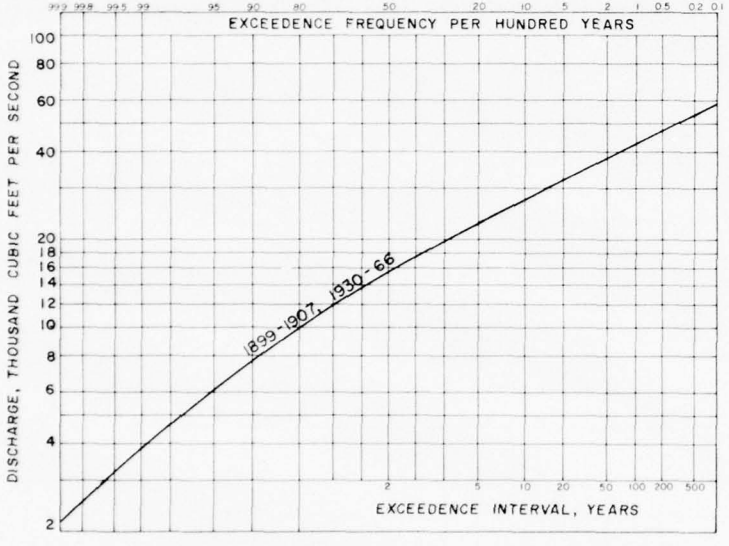


Figure 93 Frequency curve of annual peak flows, Clark Fork abv. Missoula, Mont.

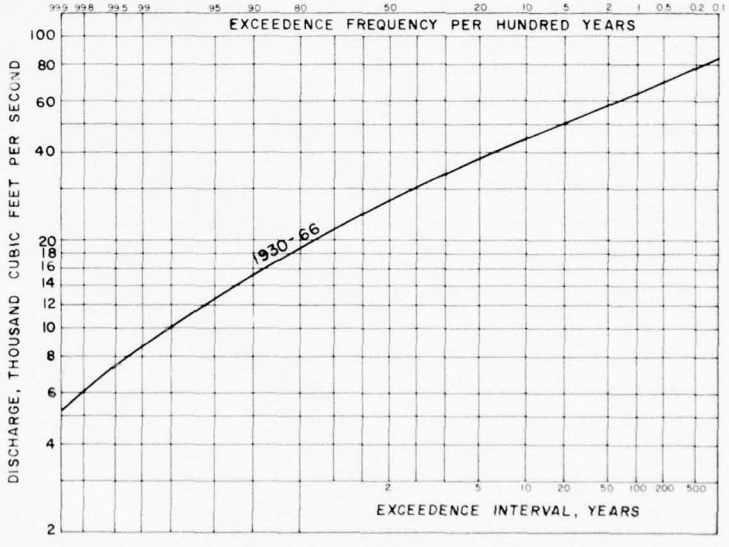


Figure 94 Frequency curve of annual peak flows, Clark Fork below Missoula, Mont.

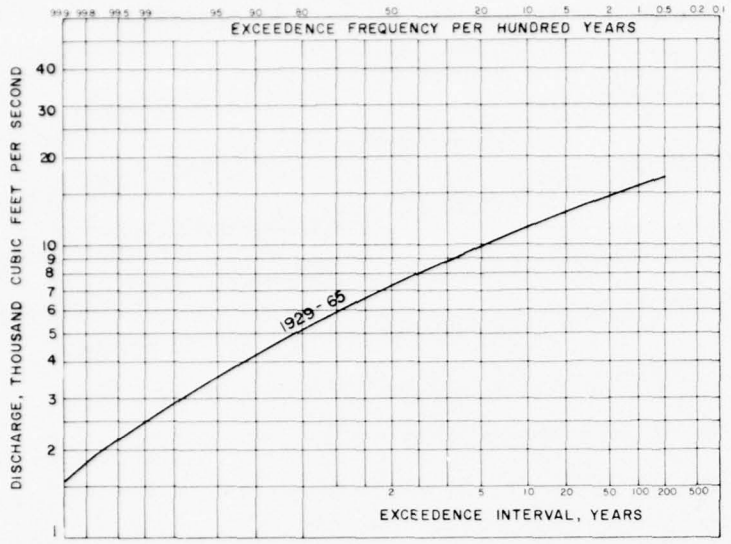


Figure 95 Frequency curve of annual peak flows, Flathead R. at Flathead, B.C.

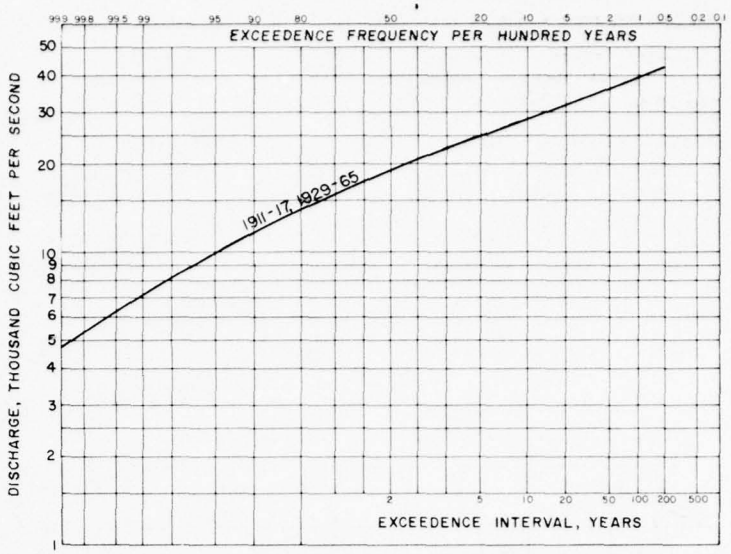


Figure 96 Frequency curve of annual peak flows, Flathead R nr. Columbia Falls, Mont.

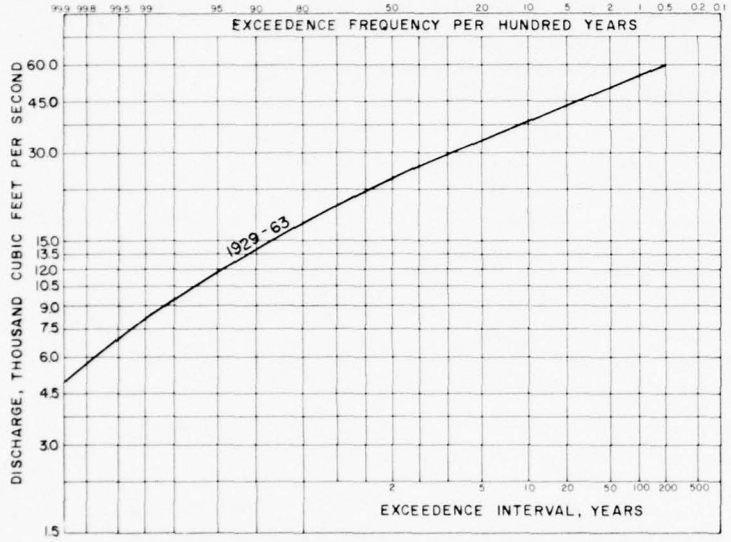


Figure 97 Frequency curve of annual peak flows, S. Fk. Flathead R. nr. Columbia Falls, Mont.

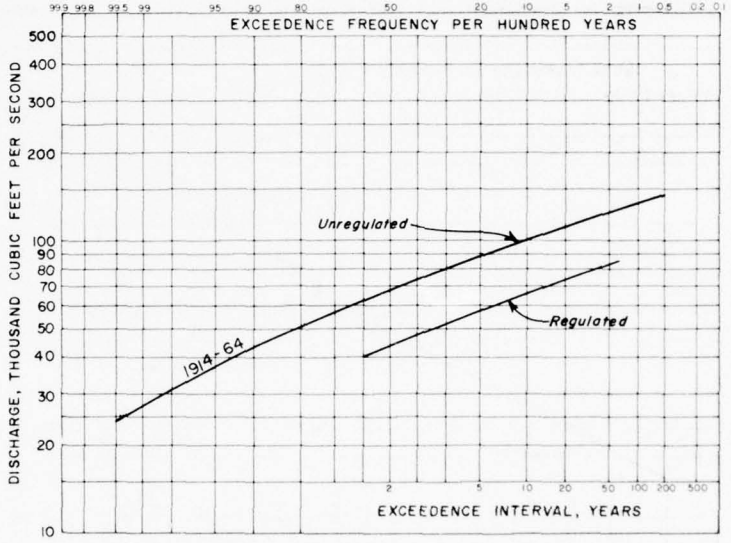


Figure 98 Frequency curve of annual peak flows, Flathead R. at Columbia Falls, Mont.

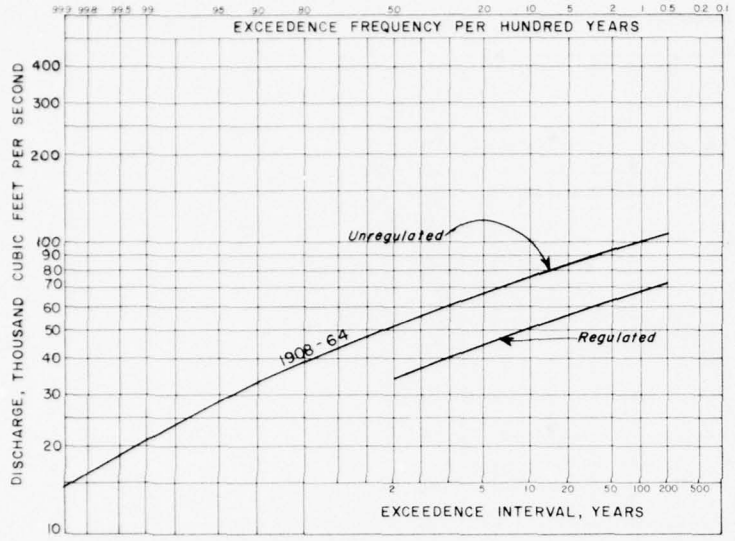


Figure 99 Frequency curve of annual peak flows, Flathead R. nr. Polson, Mont.

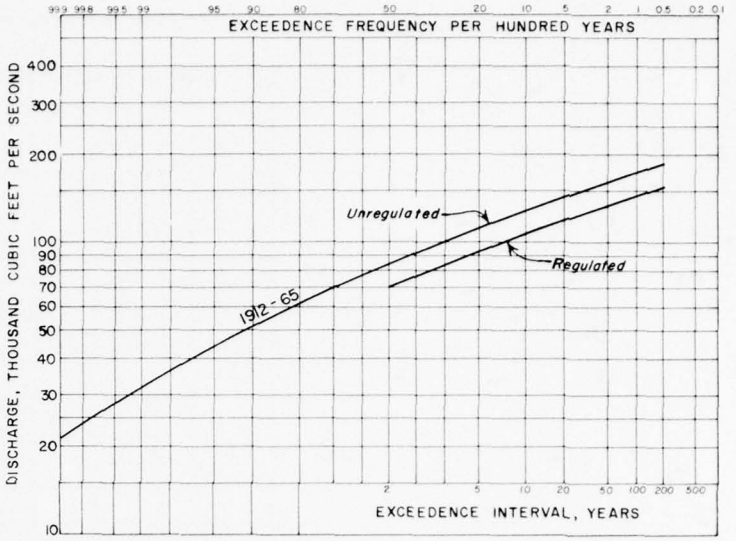


Figure 100 Frequency curve of annual peak flows, Clark Fork nr. Plains, Mont.

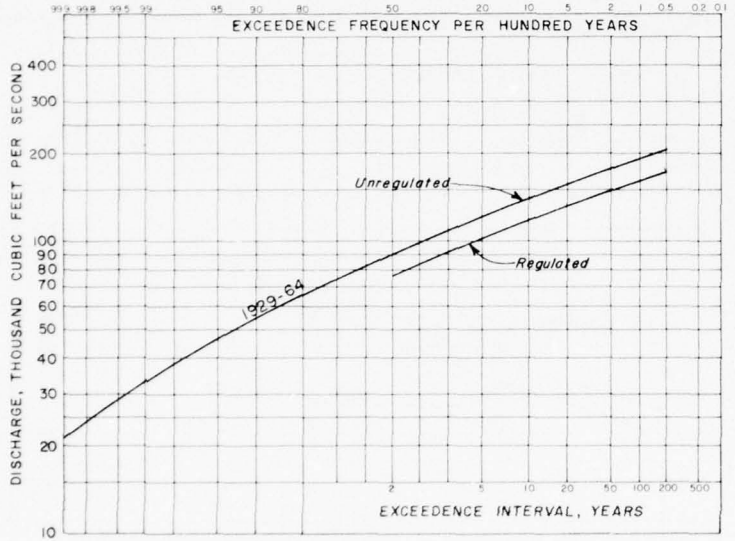


Figure 101 Frequency curve of annual peak flows, Clark Fk. at Whitehorse Rpds. nr. Cabinet, Ida.

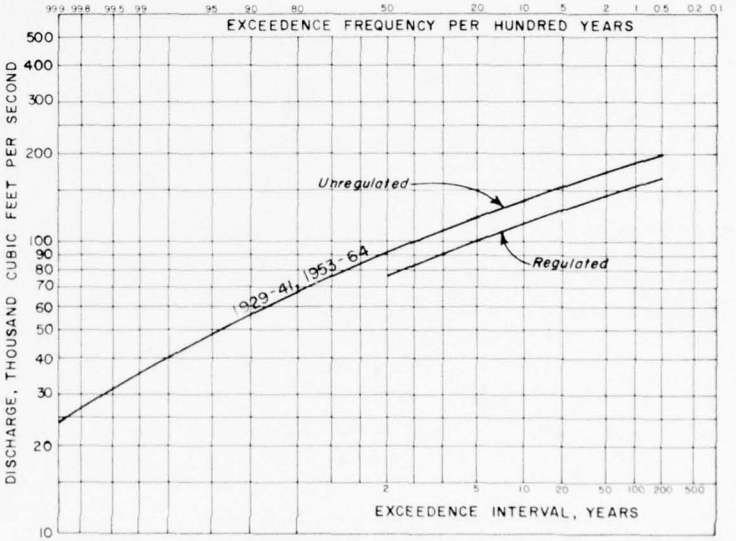


Figure 102 Frequency curve of annual peak flows, Pend Oreille R. at Newport, Wash.

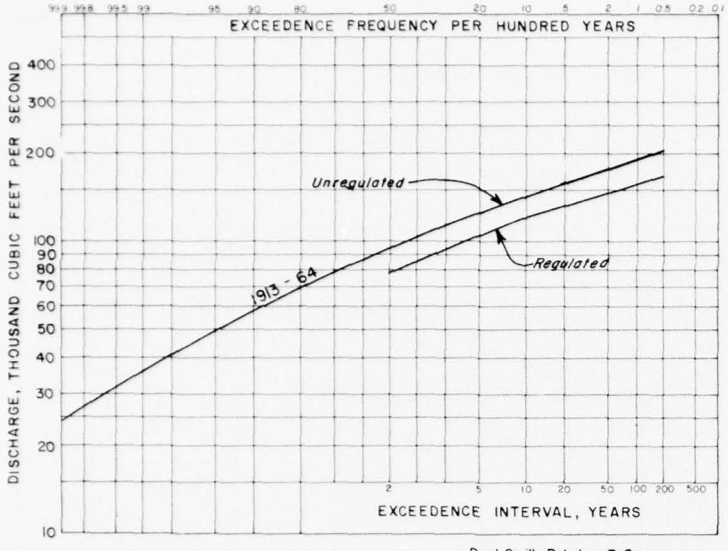


Figure 103 Frequency curve of annual peak flows, Pend Oreille R. below Z Canyon nr. Metaline Falls, Wash.

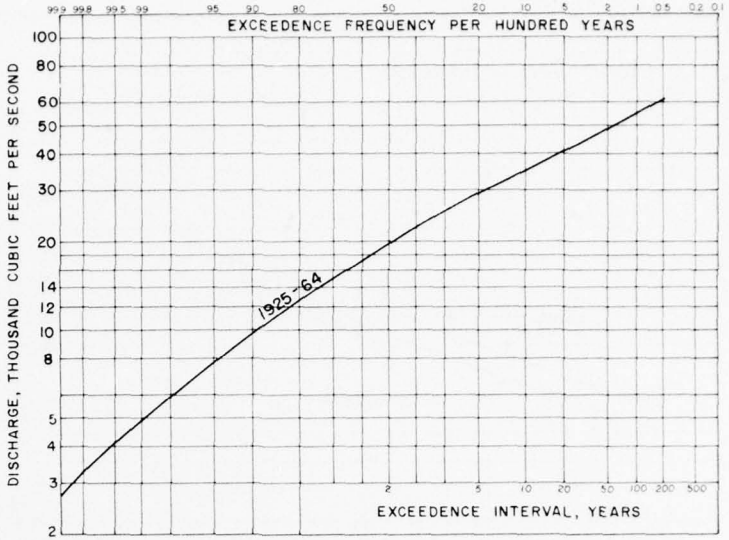


Figure 104 Frequency curve of annual peak flows, Coeur d'Alene R. nr. Cataldo, Idaho

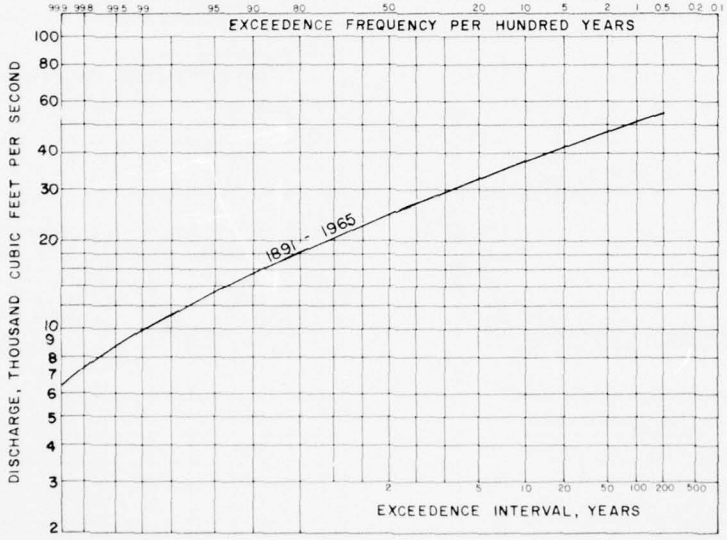


Figure 105 Frequency curve of annual peak flows, Spokane R. at Spokane, Wash.

Table 42 - Dependable Yield, Kootenay River at Newgate, B. C.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	6,079	61.2
2	1944-45	6,972	70.2
3	1929-31	7,564	76.2
4	1929-32	8,229	82.9
5	1937-41	8,258	83.2
6	1936-41	8,133	81.9
7	1935-41	8,401	84.7
8	1937-44	8,777	88.5
9	1936-44	8,636	87.0
10	1936-45	8,513	85.7
30	1929-58	9,993	100.0

Table 43 - Dependable Yield, Kootenai River at Libby, Montana

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1945	7,978	69.8
2	1944-45	8,302	72.6
3	1939-41	9,001	78.7
4	1929-32	9,434	82.5
5	1937-41	9,447	82.6
6	1936-41	9,332	81.6
7	1935-41	9,646	84.4
8	1935-42	9,992	87.4
9	1937-45	9,864	86.3
10	1936-45	9,753	85.3
30	1929-58	11,473	100.0

Table 44 - Dependable Yield, Kootenai River at Leonia, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1945	9,174	69.3
2	1944-45	9,175	69.3
3	1939-41	9,939	75.1
4	1929-32	10,812	81.7
5	1937-41	10,751	81.2
6	1936-41	10,659	80.5
7	1935-41	11,059	83.5
8	1935-42	11,483	86.7
9	1937-45	11,265	85.1
10	1936-45	11,155	84.3
30	1929-58	13,277	100.0

Table 45 - Dependable Yield, Moyie River at Eileen, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	323	37.7
2	1944-45	462	54.0
3	1929-31	511	59.8
4	1929-32	606	70.9
5	1937-41	675	78.9
6	1936-41	660	77.2
7	1935-41	685	80.1
8	1938-45	732	85.6
9	1937-45	718	84.0
10	1936-45	705	82.4
30	1929-58	854	100.0

Table 46 - Dependable Yield, Kootenai River at Porthill, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	9,921	64.9
2	1944-45	10,299	67.3
3	1939-41	11,370	74.3
4	1929-32	12,258	80.1
5	1937-41	12,359	80.8
6	1936-41	12,230	80.0
7	1935-41	12,704	83.1
8	1935-42	13,218	86.4
9	1937-45	12,949	84.7
10	1936-45	12,813	83.8
30	1929-58	15,328	100.0

Table 47 - Dependable Yield, Blackfoot River near Bonner, Montana

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	555	37.1
2	1940-41	728	49.1
3	1940-42	839	56.6
4	1939-42	985	66.5
5	1938-42	1,075	72.5
6	1937-42	1,067	72.0
7	1936-42	1,104	74.5
8	1935-42	1,144	77.2
9	1937-45	1,161	78.3
10	1936-45	1,178	79.5
30	1929-58	1,479	100.0

Table 48 - Dependable Yield, Clark Fork above Missoula, Montana

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	1,335	48.3
2	1940-41	1,499	54.3
3	1939-41	1,716	62.2
4	1939-42	1,945	70.5
5	1938-42	2,100	76.0
6	1937-42	1,984	71.9
7	1936-42	2,015	73.0
8	1935-42	2,004	72.6
9	1934-42	2,150	77.9
10	1932-41	2,177	78.9
30	1929-58	2,761	100.0

Table 49 - Dependable Yield, Clark Fork below Missoula, Montana

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1937	2,565	50.7
2	1940-41	2,797	55.2
3	1939-41	3,222	63.7
4	1938-41	3,645	72.0
5	1937-41	3,421	67.6
6	1936-41	3,553	70.2
7	1935-41	3,564	70.4
8	1935-42	3,739	73.8
9	1934-42	3,970	78.4
10	1932-41	4,009	79.1
30	1929-58	5,066	100.0

Table 50 - Dependable Yield, Flathead River at Flathead, B. C.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	419	48.6
2	1940-41	544	63.1
3	1939-41	597	69.2
4	1941-44	682	79.0
5	1940-44	668	77.4
6	1939-44	674	78.2
7	1939-45	677	78.5
8	1939-46	701	81.3
9	1936-44	711	82.4
10	1935-44	709	82.1
30	1929-58	863	100.0

Table 51 - Dependable Yield, Flathead River near Columbia Falls, Montana

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	1,383	47.8
2	1944-45	1,780	61.5
3	1939-41	1,990	68.8
4	1939-42	2,242	77.5
5	1937-41	2,296	79.3
6	1936-41	2,324	80.3
7	1939-45	2,233	77.2
8	1937-44	2,370	81.9
9	1937-45	2,349	81.2
10	1936-45	2,362	81.7
30	1929-58	2,894	100.0

Table 52 - Dependable Yield, South Fork Flathead River near Columbia Falls, Montana

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1946	1,551	46.5
2	1945-46	2,205	66.1
3	1940-42	2,282	68.4
4	1939-42	7,116	74.4
5	1938-42	7,390	77.3
6	1937-42	7,452	78.0
7	1936-42	7,536	78.8
8	1935-42	7,797	81.6
9	1937-45	7,823	81.8
10	1936-45	7,845	82.1
30	1929-58	9,552	100.0

Table 53 - Dependable Yield, Flathead River at Columbia Falls, Montana

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	5,788	60.6
2	1940-41	6,084	63.6
3	1940-42	6,596	69.0
4	1939-42	7,116	74.4
5	1938-42	7,390	77.3
6	1937-42	7,452	78.0
7	1936-42	7,536	78.8
8	1935-42	7,797	81.6
9	1937-45	7,823	81.8
10	1936-45	7,845	82.1
30	1929-58	9,552	100.0

Table 54 - Dependable Yield, Flathead River near Polson, Montana

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	6,366	58.3
2	1940-41	6,807	62.3
3	1940-42	7,572	69.3
4	1939-42	8,121	74.3
5	1937-41	8,261	75.6
6	1937-42	8,402	76.9
7	1936-42	8,531	78.1
8	1935-42	8,859	81.1
9	1936-44	8,979	82.2
10	1936-45	8,952	81.9
30	1929-58	10,906	100.0

Table 55 - Dependable Yield, Clark Fork near Plains, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	9,954	54.2
2	1940-41	10,842	59.1
3	1939-41	12,376	67.4
4	1939-42	13,257	72.2
5	1937-41	13,281	72.4
6	1936-41	13,687	74.6
7	1936-42	14,002	76.3
8	1935-42	14,398	78.4
9	1937-45	14,812	80.7
10	1936-45	14,902	81.2
30	1929-58	18,328	100.0

Table 56 - Dependable Yield, Clark Fork at White Horse Rapids near Cabinet, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	11,266	53.9
2	1940-41	12,379	59.2
3	1939-41	14,126	67.6
4	1939-42	15,122	72.3
5	1938-42	15,886	76.0
6	1937-42	15,600	74.6
7	1936-42	15,882	76.0
8	1935-42	16,359	78.2
9	1937-45	16,780	80.3
10	1936-45	16,860	80.6
30	1929-58	20,889	100.0

Table 57 - Dependable Yield, Pend Oreille River at Newport, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	14,408	58.9
2	1940-41	15,752	64.4
3	1929-31	17,240	70.4
4	1939-42	18,478	75.5
5	1937-41	18,794	76.8
6	1936-41	19,037	77.8
7	1936-42	19,392	79.2
8	1935-42	19,934	81.4
9	1937-45	20,141	82.3
10	1936-45	20,150	82.3
30	1929-58	24,457	100.0

Table 58 - Dependable Yield, Pend Oreille River below Z Canyon near Metaline Falls, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	14,861	57.5
2	1940-41	16,073	62.2
3	1939-41	17,595	68.0
4	1939-42	19,034	73.6
5	1937-41	19,028	73.6
6	1936-41	19,362	74.9
7	1936-42	19,932	77.1
8	1935-42	20,551	79.5
9	1937-45	20,819	80.5
10	1936-45	20,840	80.6
30	1929-58	25,839	100.0

Table 59 - Dependable Yield, Coeur d'Alene River near Cataldo, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	1,043	42.2
2	1929-30	1,328	53.8
3	1929-31	1,403	56.8
4	1939-42	1,722	69.7
5	1940-44	1,786	72.3
6	1939-44	1,783	72.2
7	1939-45	1,814	73.5
8	1938-45	1,921	77.8
9	1937-45	1,908	77.3
10	1936-45	1,917	77.6
30	1929-58	2,469	100.00

Table 60 - Dependable Yield, Spokane River at Spokane, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1944	2,970	45.8
2	1929-30	3,413	52.6
3	1929-31	3,559	54.9
4	1939-42	4,611	71.1
5	1937-41	4,975	76.7
6	1937-42	5,021	77.4
7	1939-44	4,115	63.5
8	1939-45	4,230	65.2
9	1938-45	4,536	70.0
10	1937-45	4,552	70.2
30	1928-58	6,485	100.0

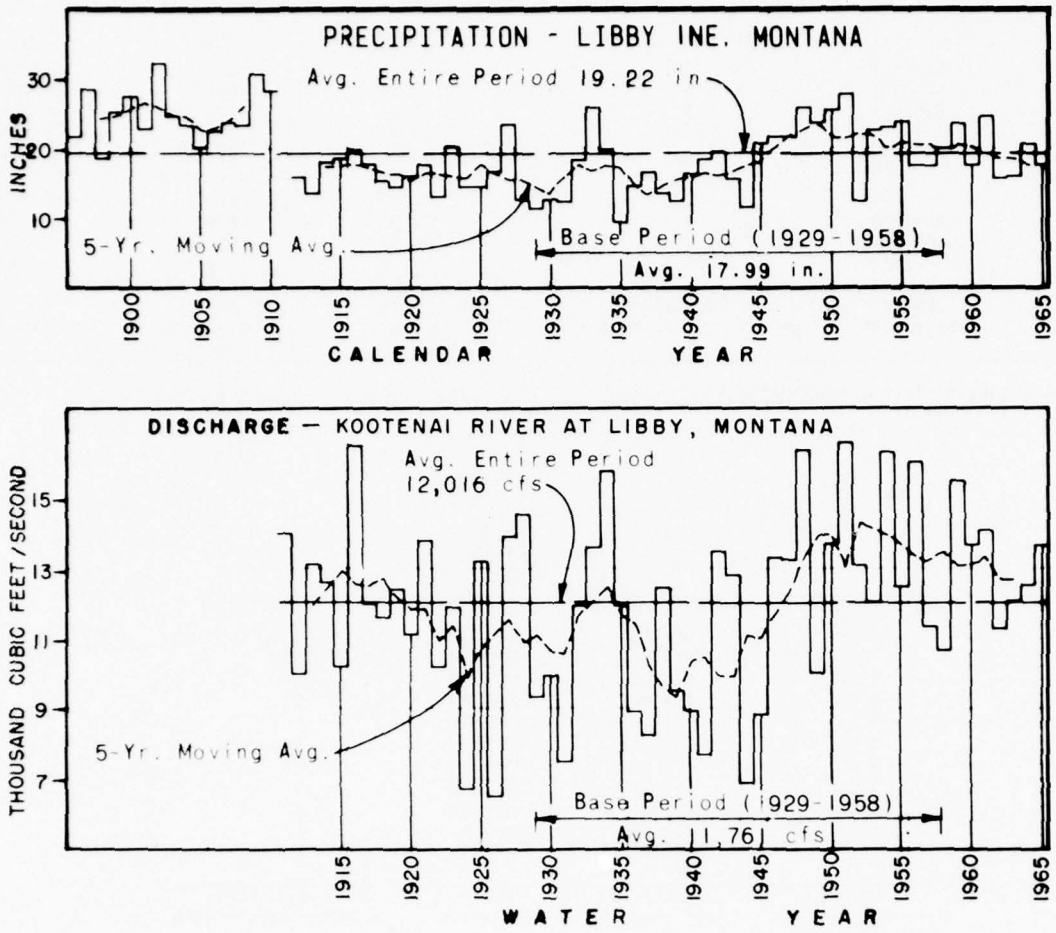


FIGURE 106. Long-term variation in precipitation and streamflow

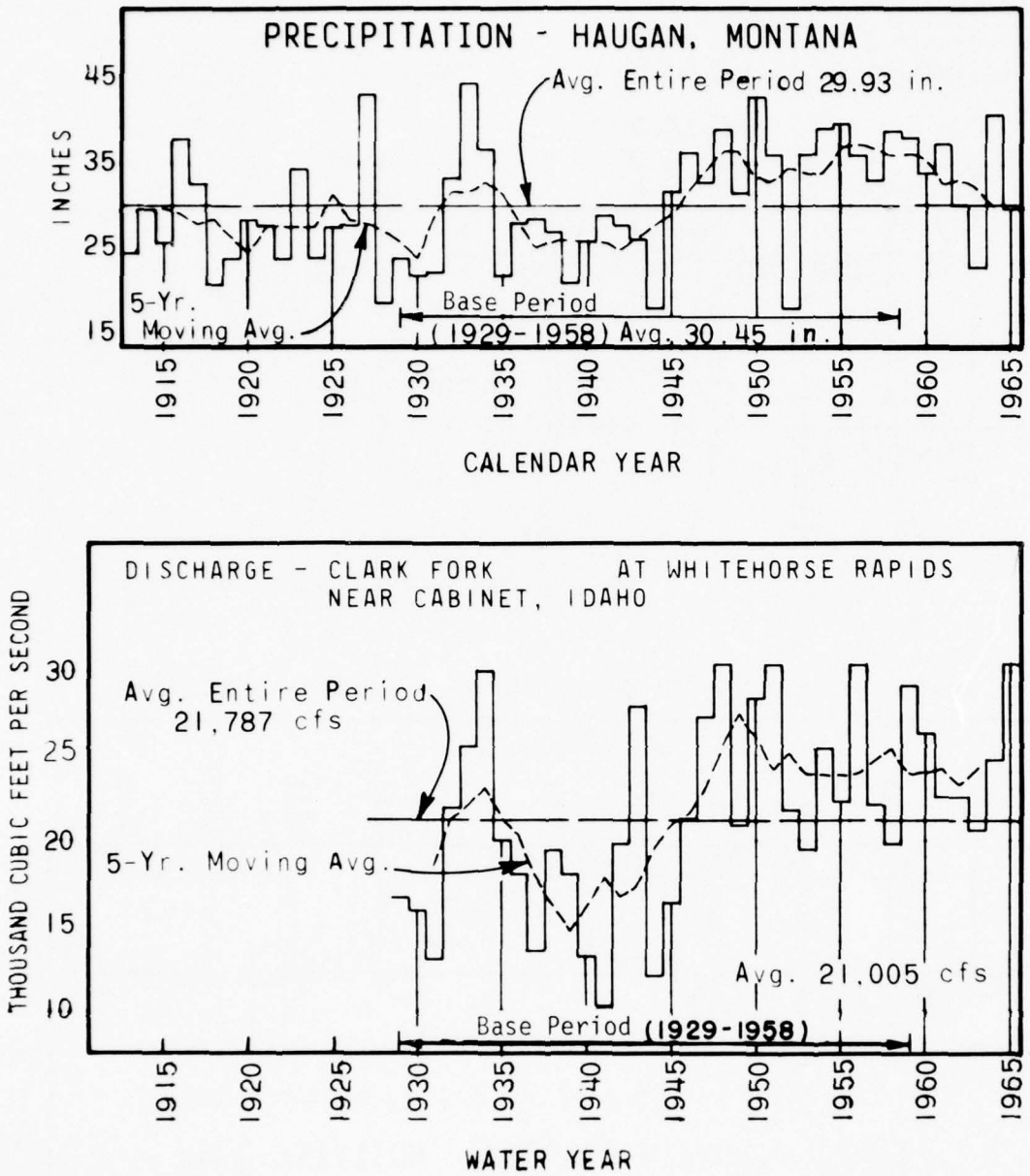


FIGURE 107. Long-term variation in precipitation and streamflow

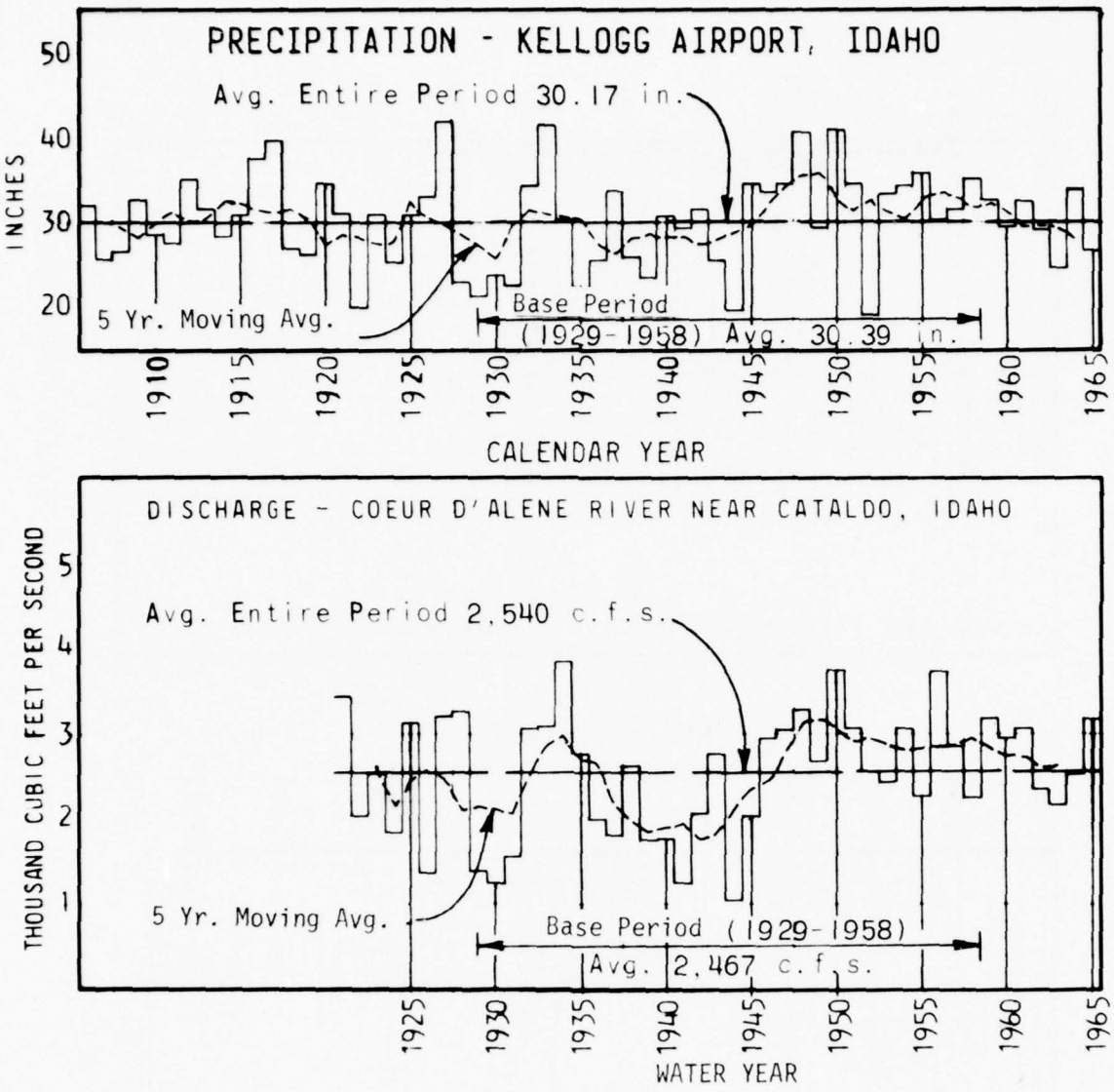


FIGURE 108. Long-term variation in precipitation and streamflow

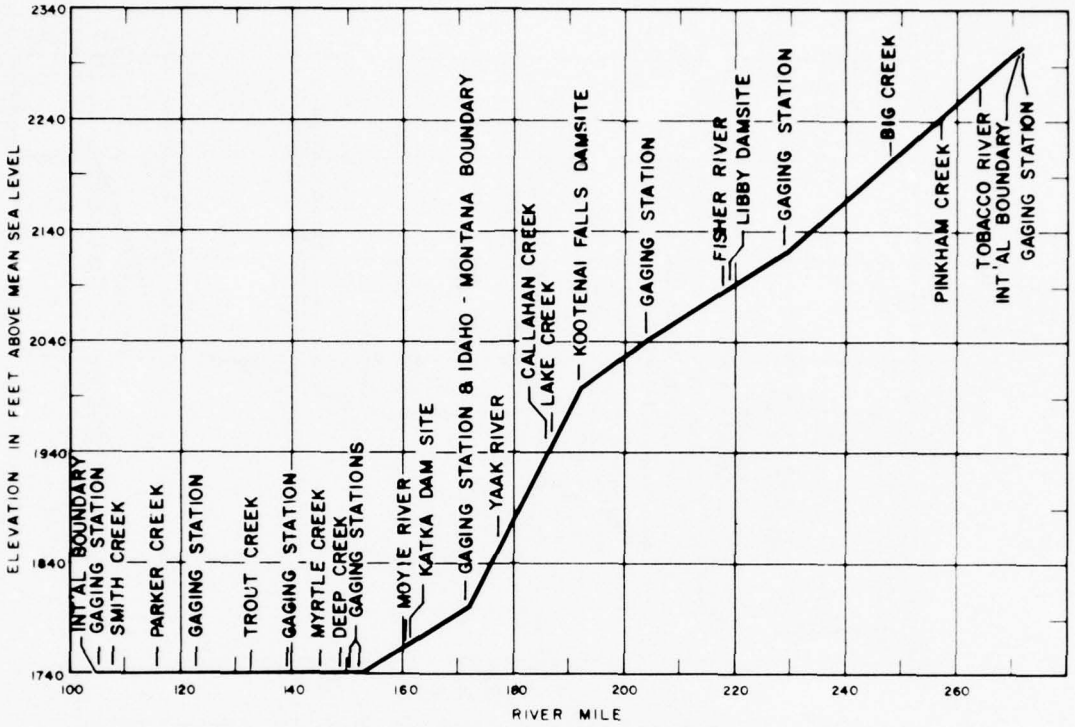


Figure 109 Stream Profile, Kootenai R., Idaho and Montana

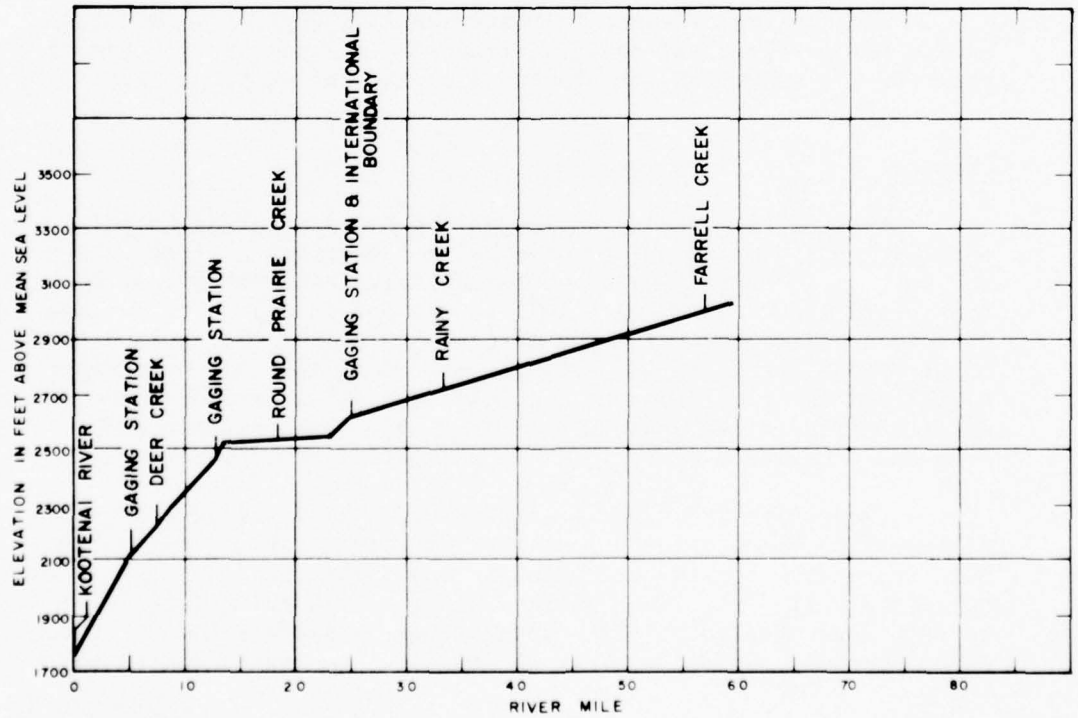


Figure 110 Stream Profile, Moyie River, Idaho

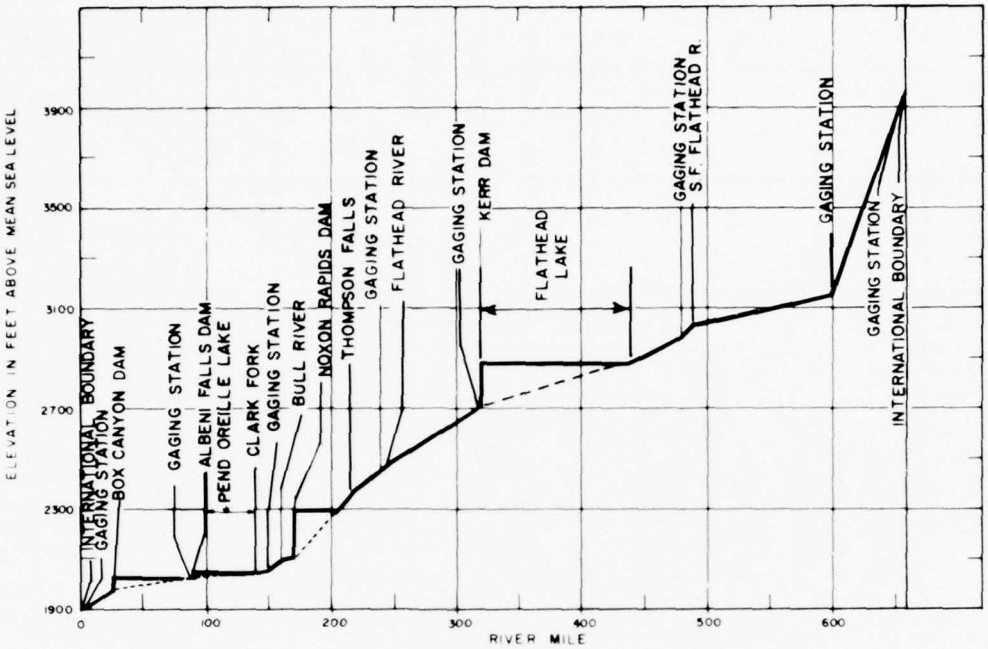


Figure III. Stream Profile, Pend Oreille - Clark Fork - Flathead R, Idaho and Montana

Quality

The quality of water in Subregion 1 is generally excellent except for pollution at certain times at a few points. Detailed data for the subregion are presented on the following pages.

Chemical

Most of the surface waters of the Kootenai, Pend Oreille, and Spokane River Basins are of excellent chemical quality. They are soft to moderately hard and the dissolved-solids concentrations seldom exceed 250 mg/l (milligrams per liter). The maximum dissolved-solids concentration of Clark Fork above Missoula and of Blackfoot River exceeds 250 mg/l at times. (4-139) Acid mine wastes and tailings from ore concentration mills have degraded water quality in the Upper Clark Fork River between Butte and Drummond, Montana. (4-75) See Appendix XII for complete details.

Except for the Coeur d'Alene River near Cataldo, Idaho, all streams sampled have contained water in which calcium, magnesium, and bicarbonate are the predominant ions. The analysis of samples collected daily from Cleur d'Alene River near Cataldo from 1953 to 1958 indicated much larger percentages of sulfate than in the other streams. During periods of low flow the concentration of

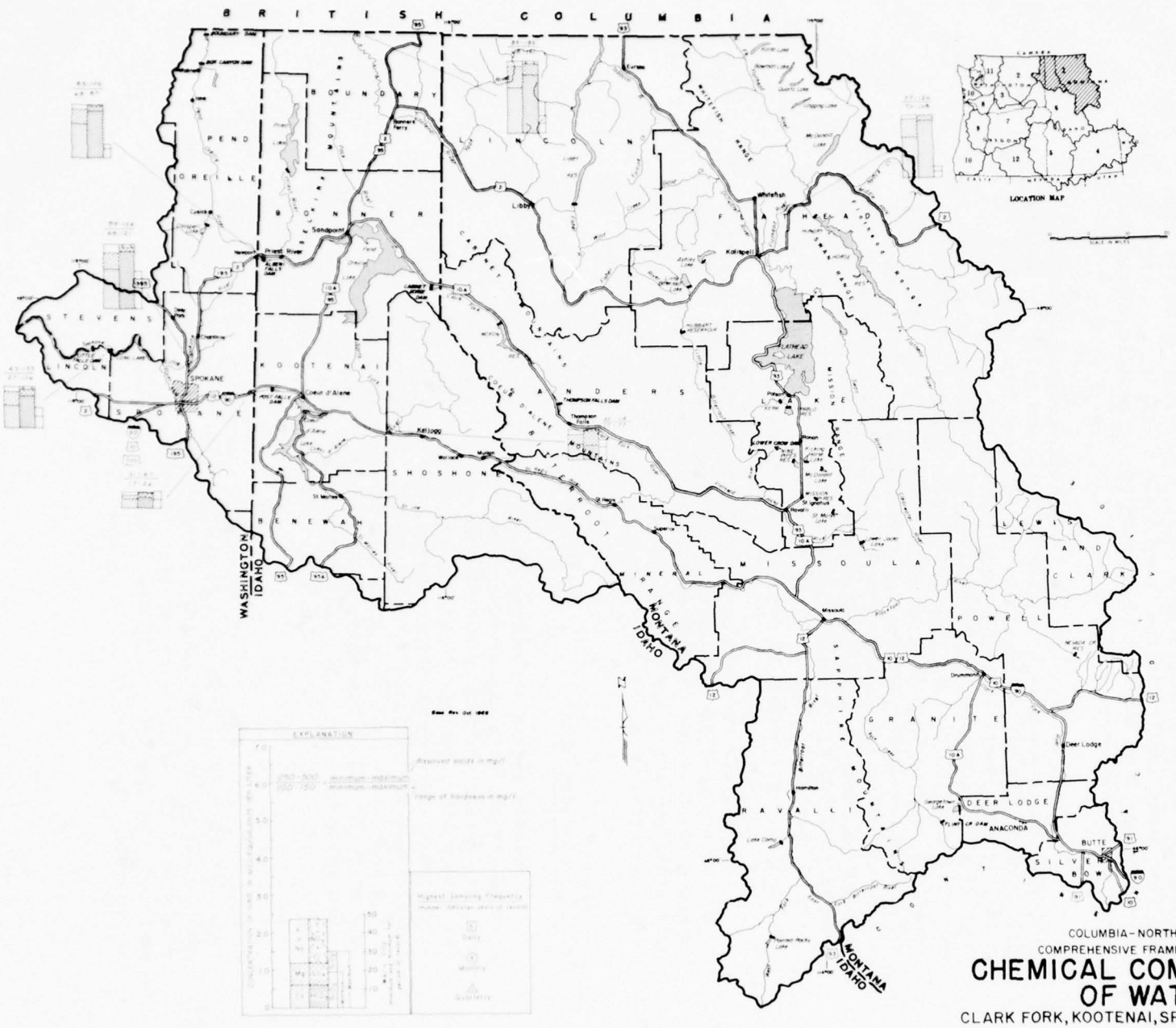
sulfate ion equals or exceeds the concentration of bicarbonate. Although the relative ionic concentrations are different, the total mineralization of the waters of Coeur d'Alene River is about the same as of other streams in the basin. The higher percentage of sulfate ion probably occurs as a result of drainage from the lead and zinc mines located in the Coeur d'Alene drainage. Over two-thirds of the lead and zinc production of the Pacific Northwest is centered in this area. (50-105)

The surface waters of the Clark Fork-Kootenai-Spokane Subregion drain areas of primarily granitic and silicious metamorphic rocks. The silica available for solution from this type of rock is considerably less than from the basaltic rocks found in much of the Columbia-North Pacific Region. Consequently, the waters of this subregion contain relatively small amounts of silica, usually averaging less than 10 mg/l. Of the streams sampled (figure 112), only the Little Spokane River at Dartford had an average silica concentration of more than 10 mg/l. Silica values of samples collected monthly from the 1960-65 water years for this river ranged from 16 to 24 mg/l. A considerable part of the flow in the lower reach of the Little Spokane River is made up of spring inflow which contains a larger amount of silica than the surface water.

The surface waters of the subregion are suitable for all normal uses except in some local areas of mine drainage. The Butte-Drummond reach of the Clark Fork River in Montana is the only known area where the water has been degraded enough to make it unsuitable for many normal uses. (4-75)

Biological-Biochemical

Streams within the subregion are generally fast moving, well-aerated streams with dissolved oxygen levels near saturation. However, during the summer months when stream flows are low and seasonal waste loadings are high, oxygen levels are depressed in three areas. Dissolved oxygen levels often drop below 2 mg/l in Ashley Creek from Kalispell to the mouth. Silver Bow Creek, part of the Clark Fork system running from Butte to Warm Springs, is completely devoid of oxygen as a result of its use as a method of transporting municipal and industrial waste downstream to oxidation ponds. During the summer, the Spokane River below Inland Empire Paper Company and the City of Spokane experiences depressions of several milligrams per liter in dissolved oxygen. This condition extends into Long Lake and becomes worse in conjunction with ponding. The lake experiences periodic algal growths and stratification, both of which add to the dissolved oxygen problem. While oxygen levels near the surface are supersaturated due to photosynthetic activity, concentrations diminish at deeper levels because of lack of reaeration opportunity and a constant drain on the oxygen



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

CHEMICAL COMPOSITION OF WATER

CLARK FORK, KOOTENAI, SPOKANE SUBREGION I

1968

FIGURE 112

resource by decaying organics. At levels below 30 feet, the water is often devoid of oxygen. Such conditions affect the Spokane River downstream from Long Lake Dam because water is released from low level outlets. The result is a low dissolved oxygen concentration for several miles beyond the dam.

Bacterial quality of the streams in the area is highly variable. In general, coliform densities below service areas are high enough to produce conditions unsuitable for water-contact recreation. Specific areas of concern include the South Fork Coeur d'Alene River with concentrations up to 24,000 organisms/100 ml; the Spokane River from Millwood to Long Lake, with levels up to 34,000 organisms/100 ml; Clark Fork River in the vicinities of Alberton, Superior, and Thompson Falls; and Ashley Creek below Kalispell, with levels up to 390,000 organisms/100 ml, recorded in 1957. Silver Bow Creek is assumed to have high bacterial concentrations since it receives raw sewage from Butte, Montana.

Sediment

Very few suspended-sediment concentration data are available in the Clark Fork-Kootenai-Spokane Subregion. During the past 2 years, concentration data have been collected on the Kootenai and Flathead Rivers. In 1950-51, data (unpublished) on suspended-sediment concentration and load were collected at two sites on the Kootenai River and at one site on the Clark Fork. Also, some data were obtained on the Coeur d'Alene in 1921-22 and on the Spokane River in 1910-11 (17). The maximum recorded concentration observed on Flathead River at Columbia Falls, Montana, was 840 mg/l in 1966, as shown on figure 113.

The map, figure 113, shows that sediment yield (30) ranges between 0.02 and 4.0 acre-feet per square mile per year and that the greatest yields are in the agricultural areas near Spokane, Washington, and below Flathead Lake in Montana. Other high yields may result from improper road construction practice, mining and grazing on some of the steep mountain slopes. The high yield of 1.5 to 4.0 occurs only in a very small area in the Hangman Creek Basin on the Washington-Idaho State line. However, sediment yields are high over most of Spokane County, Washington.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERALIZED SEDIMENT YIELD

CLARK FORK, KOOTENAI, SPOKANE SUBREGION I

1968

FIGURE 113

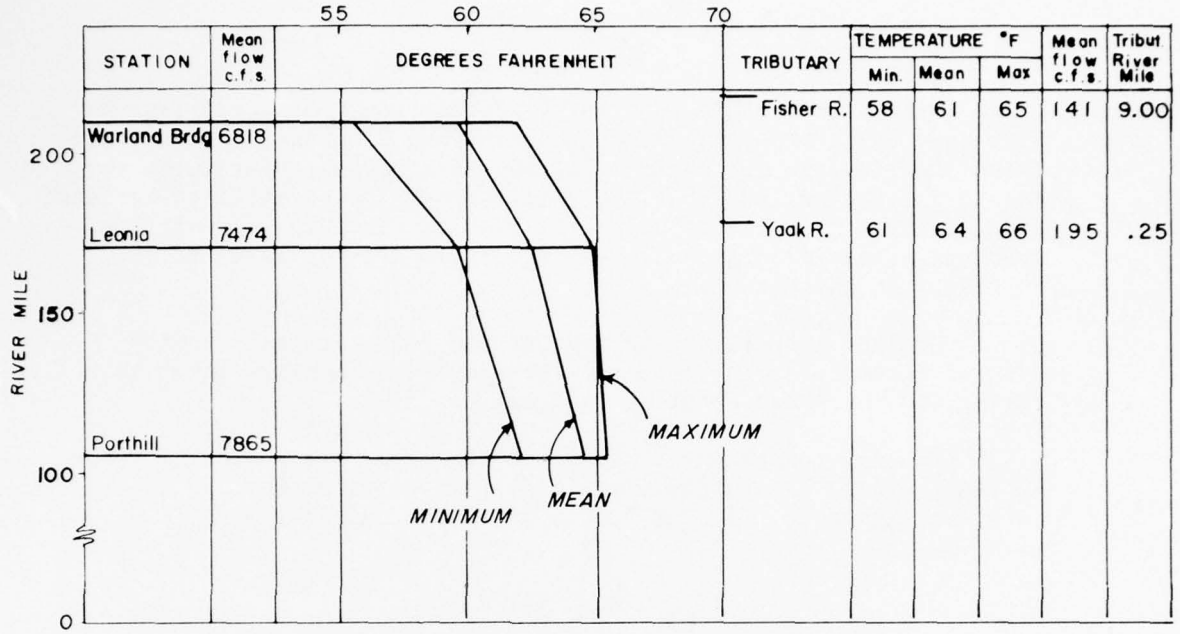


Figure 114 Water temperature profiles for August, Kootenai River, (1962—1966)

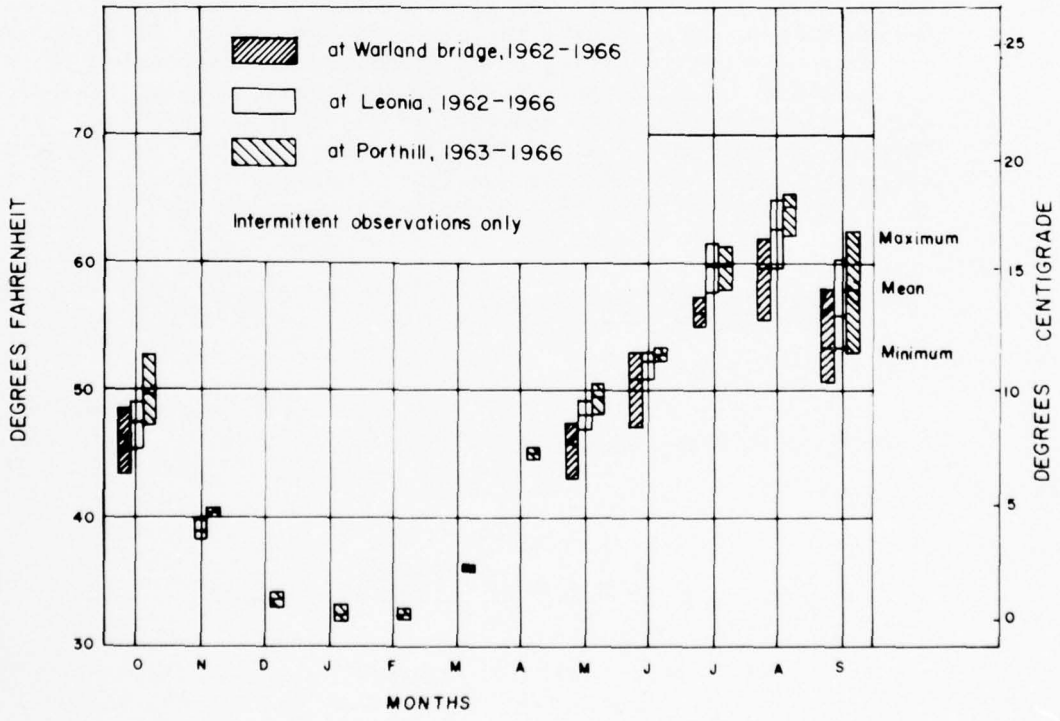


Figure 115 Monthly water temperatures, Kootenai River

Water Temperature

Water temperature data sufficient to construct profiles have been collected only for Kootenai River, as shown on figure 114. These profiles are for maximum, mean, and minimum temperatures for August for the period 1962-1966, and extend from Porthill to Warland Bridge, river mile 107 to mile 210. The temperatures of entering tributaries are also given, but their flows are too small to show an effect on the mainstem.

Maximum temperature throughout the 103-mile reach varied from 62 to 66°F. during August. The range from minimum to maximum during the month was about 10 degrees.

Monthly temperatures throughout the year are shown for three Kootenai River stations on figure 115. These vary from the high of 66°F. in August to a low of 32°F. in January and February.

GROUND WATER

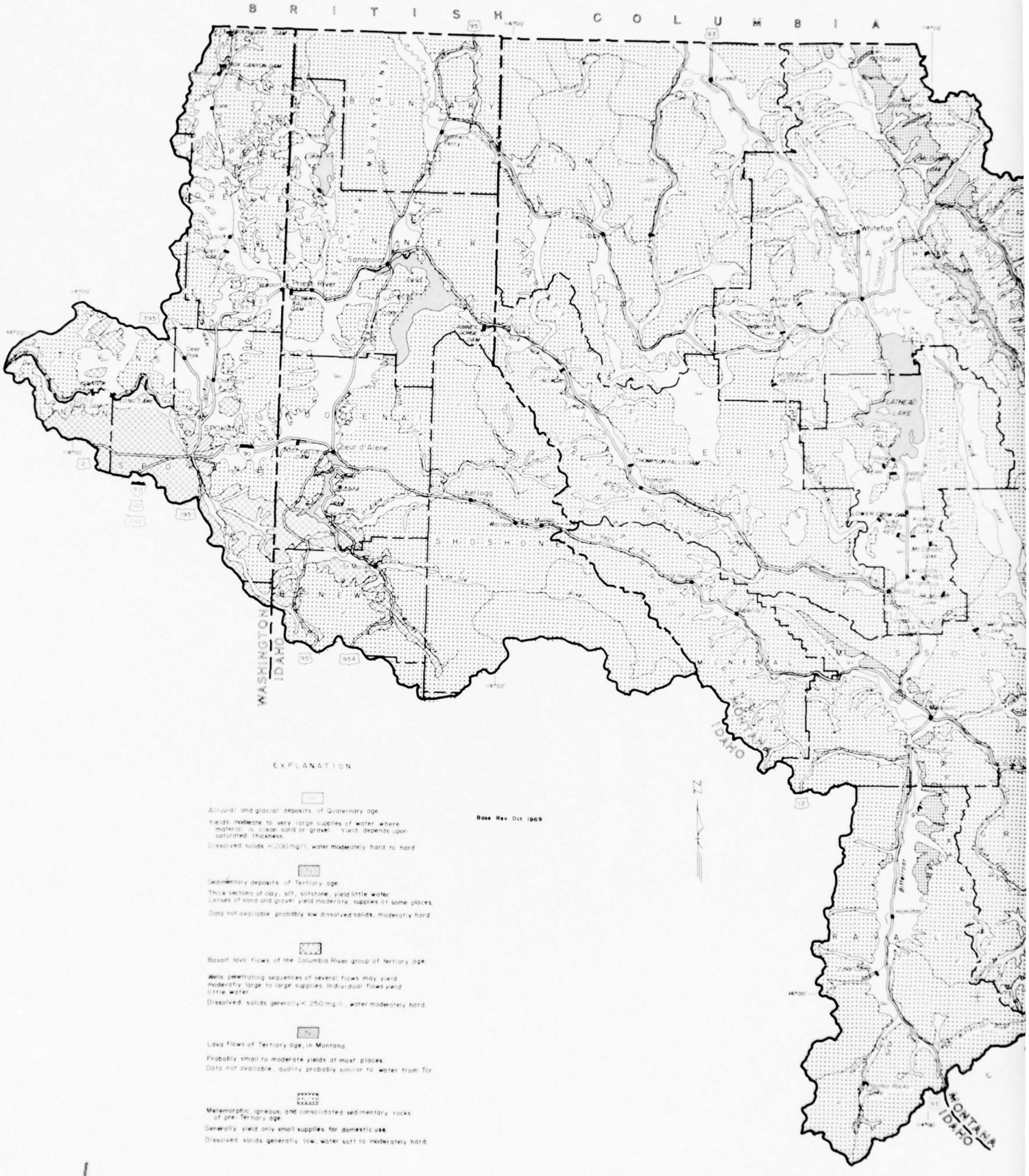
Moderate to very large supplies of ground water are available at many places in the major valleys from sand and gravel in the alluvium and glacial outwash (Qg). However, at some places the deposits are fine grained and yield little water. The basalt of the Columbia River Group (Tcr), in Idaho and Washington, is a good aquifer where the unit consists of at least several successive flows. The Tertiary volcanic rocks (Tv) and sedimentary strata (Ts) probably would yield small to moderate supplies at most places, but are largely unexplored. The pre-Tertiary rocks (pT) of the mountain areas generally have low permeability; however, a deeply weathered zone supplies base flow to streams and recharge to aquifers in the valleys.

The chemical quality of ground water generally is good to excellent for most uses. Present development is only a small fraction of the available supply.

More than a dozen reports describe aquifers and ground-water occurrence in parts of Subregion 1. Most of them are listed in references 1, 34, 59, 62, 63, 74, 75, 77, 119, 130, 131, 159, 182, and 201.

Aquifer Units and Their Hydrologic Characteristics

Four aquifer units have been delineated in Subregion 1; all are important in the hydrologic regimen, but in somewhat different ways. Aquifer units are shown on the map, figure 116, which is based on the geologic maps of Idaho (133), Montana (132), and


B R I T I S H C O L U M B I A
BOUNDARY
Sandpoint
Priest River
Deer Park
SPOKANE
Coeur d'Alene
Kellogg
Wallace
Missoula
Whitefish
Libby
Kalispell
FLATHEAD LAKE
Thompson Falls
Mullan
Bitterroot
WASHINGTON
IDAHO
MONTANA
IDAHO
MONTANA
IDAHO
EXPLANATION
Alluvial and glacial deposits of Quaternary age.
Yields moderate to very large supplies of water where material is clean sand or gravel. Yield depends upon saturated thickness.
Dissolved solids <200 mg/l, water moderately hard to hard.
Sedimentary deposits of Tertiary age.
Thick sections of clay, silt, siltstone, yield little water.
Lenses of sand and gravel yield moderate supplies at some places.
Data not available, probably low dissolved solids, moderately hard.
Basalt lava flows of the Columbia River group of tertiary age.
Wells penetrating sequences of several flows may yield moderately large to large supplies. Individual flows yield little water.
Dissolved solids generally < 250 mg/l, water moderately hard.
Tv
Lava flows of Tertiary age, in Montana.
Probably small to moderate yields at most places.
Data not available, quality probably similar to water from Tcr.
Metamorphic, igneous, and consolidated sedimentary rocks of pre-Tertiary age.
Generally yield only small supplies for domestic use.
Dissolved solids generally low, water soft to moderately hard.
Base Rev. Oct. 1969



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

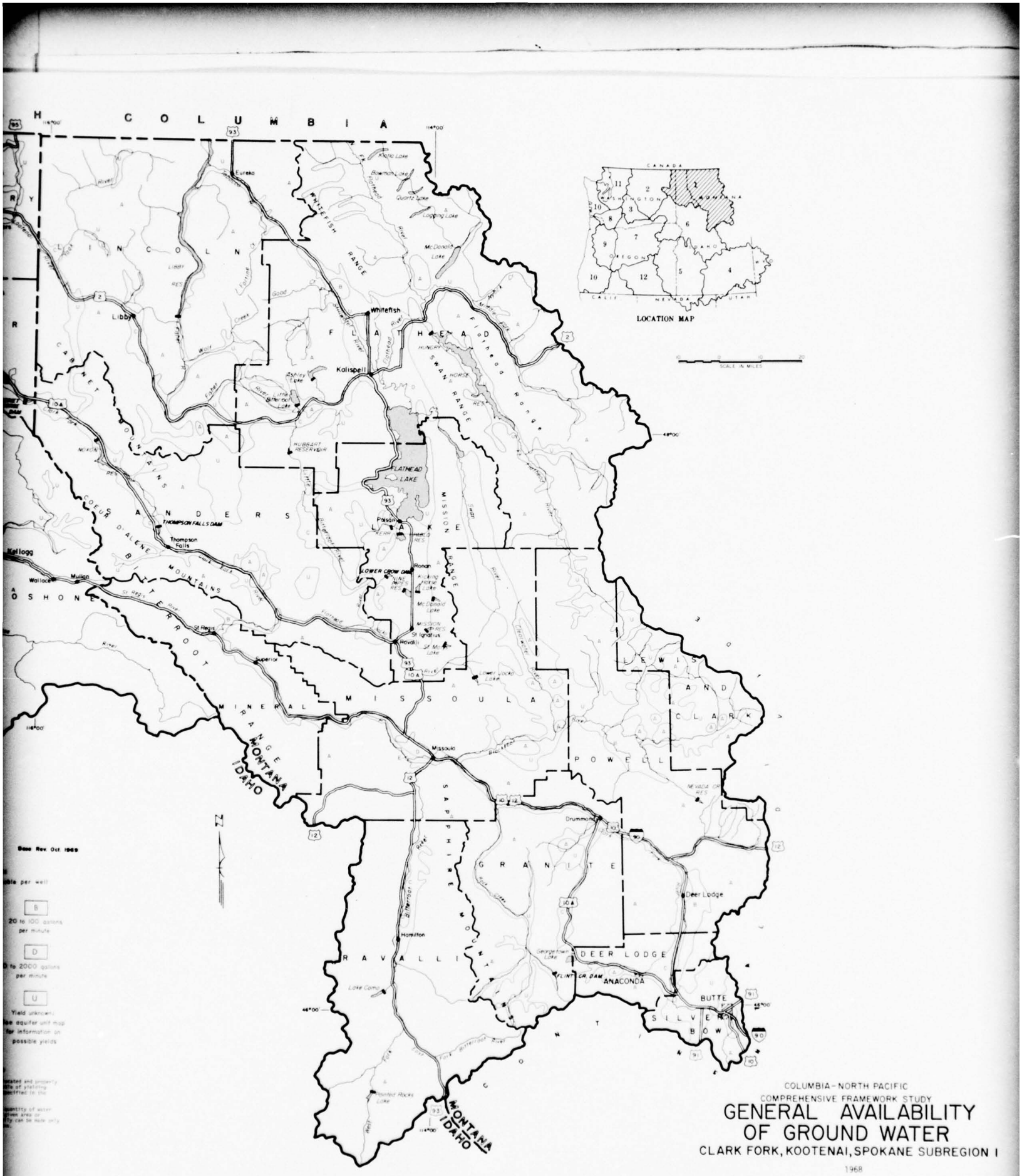
AQUIFER UNITS

CLARK FORK, KOOTENAI, SPOKANE SUBREGION I

1968

FIGURE 116


B R I T I S H C O L U M B I A
BOUNDARY DAM
BOX CANYON DAM
Metaline
Ione
BOUNDARY
PEND OREILLE
Priest River
Newport
ALBENI FALLS DAM
Sandpoint
Bonners Ferry
SELKIRK MOUNTAINS
BONNER
Gatsick
Libby
LINCOLN
CABINET MOUNTAINS
CABINET GORGE DAM
Whitefish
Kalispell
FLATHEAD LAKE
HUBBART RESERVOIR
STEVENS
Chattaroy
SPOKANE
LITTLE FALLS DAM
KOOTENAI
Coeur d'Alene
POST FALLS DAM
COEUR D'ALENE MOUNTAINS
THOMPSON FALLS DAM
Thompson Falls
Kellogg
Wallace
Mullan
SHOSHONE
BITTERROOT MOUNTAINS
St. Maries
St. Regis
Superior
BENEWAH
MINERAL
WASHINGTON
IDAHO
MONTANA
IDAHO
Lake Como
Painted Rocks Lake
Base Rev. Oct. 1969
EXPLANATION
Quantity generally available per well
A
1 to 20 gallons per minute
B
20 to 100 gallons per minute
C
100 to 500 gallons per minute
D
500 to 2000 gallons per minute
E
More than 2000 gallons per minute
U
Yield unknown. See aquifer unit map for information on possible yields
Limits of yield
The map shows areas where property located and properly constructed wells generally are capable of producing amounts of water within the limits specified in the legend above.
The map does not indicate the total quantity of water that may be available in any given area, nor, in most cases, where determinations beneficially can be made only on the basis of special investigations.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERAL AVAILABILITY OF GROUND WATER

CLARK FORK, KOOTENAI, SPOKANE SUBREGION I

1968

FIGURE 117

Washington (54). The alluvial, glaciofluvial, and glaciolacustrine deposits of Quaternary age (Qg), compose the most important aquifer unit (abbreviated to alluvial-aquifer unit hereafter). The alluvial deposits include gravel, sand, and silt underlying floodplains and terraces along most of the streams in the subregion. Glacial outwash deposits of coarse sand and gravel form deep fills in some valleys and basins; fine sand, silt, and clay deposited in glacial lakes are extensive at other places. Glacial till and poorly sorted unstratified drift are common at higher elevations. Alluvial and glacial outwash deposits in the alluvial-aquifer unit furnish most of the large supplies to wells in the subregion. Yields of wells in the vicinity of Spokane are limited by the capacities of the pumps; yields of 5,000 to 10,000 gpm (gallons per minute) are not uncommon. Large yields also are obtained from the glacial outwash in Rathdrum Prairie; underflow through the 3-mile width of the valley at the Idaho State line is estimated to be about 1,000 cfs (cubic feet per second). Yields of 1,000 gpm are obtained from the alluvium and glacial outwash in parts of the Bitterroot, Missoula, Deer Lodge, Kootenai, and Flathead Valleys in Montana. At other places, as north of Pend Oreille Lake and at places in Montana, the deposits are fine-grained sand and silt, and yield only small to moderate supplies. At many places, especially in the headwaters areas of many streams, these deposits have not been explored.

Sedimentary formations of Tertiary age (Ts) constitute the second aquifer unit. This unit occurs rather widely as a partly dissected basin fill, flanking and underlying several major valleys. It consists mostly of poorly consolidated gravel, sand, silt, and clay, but includes some tuffaceous material and, locally, lignite and bentonite. Thick sections of clay, silt, and tuffaceous clay occur at many places and yield little water. Sandy and gravelly strata produce moderate to moderately large supplies. The aquifer unit is important in the recharge and storage of ground water and is known to yield moderate supplies of ground water at a few places. However, at most places there has been little exploration for ground water in the unit. It probably has considerable potential for additional development in some areas.

The third aquifer unit is the volcanic rocks of Tertiary age, subdivided into the basalt of the Columbia River Group in Washington and Idaho (Tcr), and into Tertiary volcanic rocks, undifferentiated (Tv), in Montana. The Columbia River Group consists chiefly of widespread flows of medium to dark gray basalt underlying broad uplands. At a few places the basalt also occurs as intracanyon flows. Tuffaceous silt, clay, and sandstone of the Latah Formation occur as interbeds in the basalt. The lower parts of the flows generally are dense and massive; columnar jointing is common. The upper parts usually are vesicular, with platy or blocky jointing. The bottom and central parts of the flow are mostly

impermeable, but the upper few feet of the flow and openings at the base of the overlying flow form permeable zones at many places. In general, well yields depend upon the number of inter-flow zones penetrated; yields commonly average about 1 gpm per foot of basalt penetrated. The sedimentary interbeds generally have low permeability and yield little water. The basalt yields moderate to large supplies where sections several hundred feet thick are saturated. Little is known about the volcanic rocks in Montana, but they probably will yield moderate supplies where thick sequences are saturated.

Consolidated sedimentary, igneous, and metamorphic rocks of pre-Tertiary age (pT), which generally form the mountain ranges, constitute the fourth aquifer unit. They generally have low porosity and permeability and yield only small supplies to wells. However, some limestone, sandstone, or other strata may yield moderate to moderately large supplies at a few places. The aquifer unit is an important source of supply for thousands of shallow wells and springs used for rural domestic and stock supplies. In many places, it is deeply weathered, and the weathered zone, together with talus and other debris, forms a porous, shallow reservoir that furnishes base flow to streams in the subregion. Because it is thin, and because the mature topography results in steep hydraulic gradients and many discharge points, this shallow upper zone of the aquifer unit is depleted rather rapidly.

Brief descriptions of the aquifer units, their general hydrologic characteristics, and the general quality of the water yielded by them are given in table 61. The general availability of ground water is shown on the map, figure 117. For maximum utility, that map and the aquifer-unit map, figure 116, should be used together.

Because of differences in thickness and water-bearing characteristics from place to place, the yields of wells in any aquifer unit vary greatly. Generally, the yield range given applies to about 80 percent of the wells; roughly 10 percent may yield more and 10 percent less than the range given.

Table 61 - Description of Aquifer Units and Their Hydrologic Characteristics, Subregion 1

Map Symbols and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
Qg: Stream alluvium, glacial drift and fluvio-lacustrine deposits of Pleistocene and Holocene age.	Sand, gravel, and silt in alluvial deposits; sand and gravel outwash deposits; till; unsorted glacial drift. Glacio-lacustrine deposits generally clay, silt, very fine sand, with occasional lenses of coarse sand and gravel.	Coarse outwash of Rathdrum Prairie-Spokane Valley forms an exceedingly porous and permeable aquifer. Moderate to large yields are also obtained from wells in some valleys in Montana. Fine-grained sediments deposited in glacial lakes yield little water.	Dissolved solids generally less than 200 mg/l; total hardness of water 80 to 150. Fluoride, sodium adsorption ratio low; iron generally is not a problem.
Ts: Tertiary sedimentary deposits, undifferentiated, mostly in valleys of western Montana. May include some early Pleistocene-terrace deposits.	Mostly poorly consolidated gravel, sand, silt, and clay; includes some tuffaceous material and, locally, lenses of lignite and bentonite;	Thick sections of clay, silt, tuffaceous clay at many places, yield very little water. Sandy and gravelly strata may produce moderate to moderately large supplies of water.	Dissolved solids generally less than 500 mg/l. Sodium adsorption ratio 10 to 15 at some places.
Tcr: (Washington and Idaho) Flood-type basaltic lava flows forming plateaus; some intercanyon flows. Interbeds of Latah Fm. included. Miocene and early Pliocene in age.	Medium to dark gray, dense to vesicular basalt, frequently with very well-developed columnar jointing. Lower parts of flows usually dense, massive; upper parts vesicular, with platy or blocky jointing.	Bottom and central parts of flow mostly impermeable; upper few feet of flow and zone of openings at base of succeeding flow forms permeable zone.	Dissolved solids generally less than 250 mg/l; water soft to moderately hard; fluoride, sodium adsorption ratio low; silica generally 40-50 mg/l.
Tv: (Montana) Tertiary lava flows, undifferentiated.	Flows and associated pyroclastics; chiefly latite, quartz latite and andesite; some rhyolite and basalt. Contains some intercalcated sedimentary beds.	Data not available. Probably only small to moderate yields at most places. Thicker flow sequences may yield larger supplies.	No data available. Probably similar to water in Tcr.
pT: Pre-Tertiary rocks, undifferentiated. Includes Precambrian Belt Series, Paleozoic and Mesozoic sedimentary strata and Cretaceous-early Tertiary intrusives.	Quartzite, argillite, impure dolomite with some associated volcanic rocks; dolomite, limestone, sandstone, shale, evaporite. Intrusive rocks include quartz monzonite, granodiorite, gneissic and schistose around borders.	The rock units generally have low porosity and permeability and yield only small supplies to wells. A moderately thick weathered zone serves as shallow ground-water reservoir and maintains the base flow of streams.	Few data available. Water generally low in dissolved solids; soft to moderately hard.

Water in Storage

A rough estimate of the quantity of water stored in each aquifer unit, in a specified depth interval below the water table, is given in table 62 as shown below.

Table 62 - Storage, Recharge, and Discharge of Ground Water in Aquifer Units, Subregion 1

Aquifer Unit	Area		Storage			Annual Natural Recharge and Discharge			
						Inches Over Area		(1,000 Ac-Ft)	
	Sq. Mi.	Acres (1,000)	Specific Yield (percent)	Depth Used (ft)	Water (1,000 ac-ft)	Gross	Net	Gross	Net
Qg	8,000	5,100	20	50	51,000	24	12	10,200	5,100
Tcr	990	630	1	50	215		4		210
Tv	360	230	1	50	115		4		75
Ts	840	540	5	50	1,350		6		270
pT	25,500	16,300	2	50	16,300		10		13,500
TOTAL (rounded)	35,700	22,800			69,000				19,000

The specific yield of the alluvial-aquifer unit (Qg) probably ranges from a few to 25 or 30 percent. There is a higher percentage of clean, coarse-grained material in the uppermost 50 feet of the saturated zone than in the rest of the unit, and the specific yield of that zone is estimated to be 20 percent. The specific yield of the basalt (Tcr) and the Tertiary volcanic rocks (Tv) is estimated to be on the order of 1 percent. The Tertiary sedimentary rocks (Ts) are predominantly fine grained, and partly consolidated or cemented at places. A specific yield of 5 percent is a reasonable estimate.

The pre-Tertiary rocks (pT) have very low porosity and specific yield at depth where weathering has not penetrated and joints and other fractures are tightly sealed by the weight of the overlying rock. However, they are deeply weathered in many areas, and a specific-yield estimate of 2 percent for the uppermost 50 feet of saturation seems reasonable.

A storage depth of 50 feet was used for all aquifer units in the subregion. According to the table, about 69 million acre-feet of water is stored in the first 50 feet below the water table; nearly 75 percent of this is in the alluvial aquifer unit. Much of the water is stored in fine-grained alluvial and lacustrine deposits of low permeability and is not readily available. However, large-scale pumping from more permeable deposits would induce

movement of water from the low-permeability materials to the high-permeability materials. It seems probable that the available ground-water supply in storage is many million acre-feet.

Natural Recharge and Discharge

Recharge to aquifers in Subregion 1 is derived from direct precipitation, from seepage from streams, and from irrigation. The pre-Tertiary rocks crop out in the mountains, where the precipitation is greatest, and are recharged in the fall and winter from direct precipitation, and in the spring from melting snow. The Tertiary volcanic rocks (Tcr and Tv) and the Tertiary sediments (Ts) crop out in rolling uplands, benches, and terraces. Those units are recharged by precipitation during the winter and spring, snowmelt in the spring, and influent seepage from streams. The alluvial-aquifer unit (Qg) underlies floodplains and terraces and is recharged largely by effluent seepage from streams and by seepage from irrigation. Most of the recharge occurs during the period of April-September. The greatest rise in the water table, usually, is in April, May, and June. Generally, the seasonal rise amounts to 5 to 10 feet; however, this does not represent all the recharge to the aquifers. Considerable recharge is required merely to offset discharge during periods when the water table is maintained at higher levels and there may be considerable recharge even during periods of falling water levels. Average annual recharge to the alluvial and glacial deposits may be equivalent to a total rise in the water table of more than 10 feet. Assuming a specific yield of 20 percent for these deposits, the total annual recharge would be about 2 feet of water. Hydrographs of representative wells are shown in figure 118.

A detailed study of inflow to and outflow from the glacio-fluvial aquifer underlying Rathdrum Prairie-Spokane Valley was made by Thomas. (159) He concluded that the average annual inflow to the aquifer was 1,100 cfs during the period 1951-59. As the surface area of the aquifer is about 155 square miles, this quantity represents an average annual recharge of about 8 feet over the area. That aquifer is thicker, more porous, and more permeable than any other aquifer in the alluvial-aquifer unit and certainly cannot be considered representative. However, it does give an idea of the large volumes of water that the more productive alluvial aquifers are capable of receiving and transmitting.

Although 24 inches of water over the area of the alluvial-aquifer unit may represent average total annual recharge, much of this water had already been through the ground water-surface water cycle that involves aquifer units underlying high benches and mountains. Therefore, for table 62, the net recharge was estimated to be 12 inches over the area.

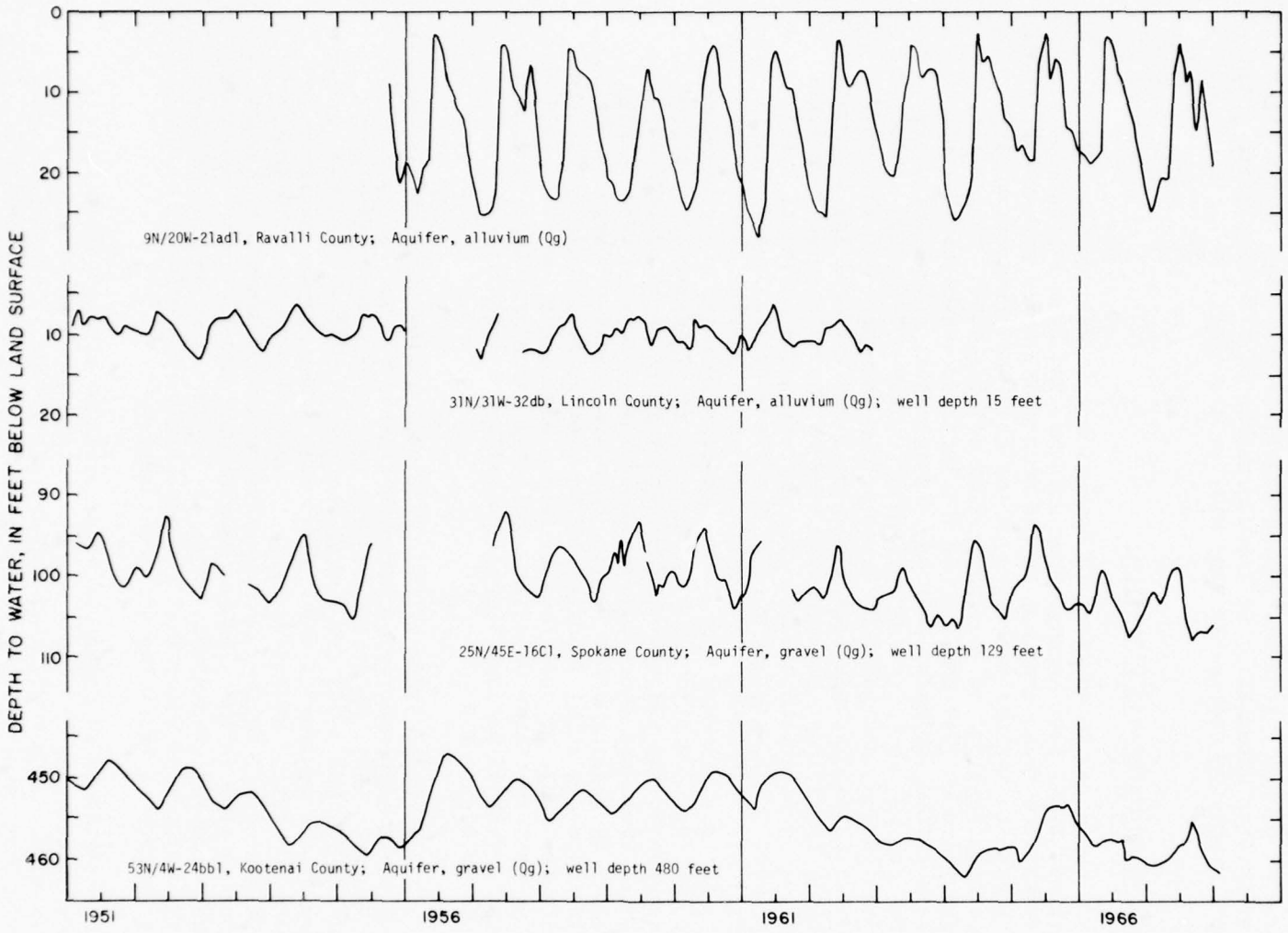


Figure 118 Hydrographs of selected wells in subregion I

No records of water-level fluctuations are available for the other aquifer units so that fluctuations cannot be used to estimate recharge. In contrast to recharge, which is an intermittent process, ground-water discharge is a continuous process. Maximum discharge occurs when the hydraulic gradient is steepest and, except for short periods of flood stage in areas adjacent to floodplains, this occurs when the water table is highest. Base flow supplied by ground water to streams during prolonged dry periods often represents minimum ground-water discharge.

A rough measure of the ground-water component of stream dishcarge was made by studying streamflow hydrographs as previously described. Generally, the ground-water component for streams draining aquifer units other than the alluvial aquifer unit is 20 to 35 percent of the total discharge. This represents a volume of water equivalent to a range of 4 to 12 inches over the area. Estimates of recharge and discharge for the Tcr, Tv, Ts, and pT aquifer units in table 62 were derived in this way.

The estimates of average annual natural recharge and discharge are given in table 62. The total annual recharge and discharge is estimated to be about 24 million acre-feet. However, about 5 million acre-feet is believed to go through two cycles of recharge and discharge before leaving the basin, so net recharge and discharge would be about 19 million acre-feet. About 13 million acre-feet of water is recharged to and discharged from the pre-Tertiary aquifer unit. This is a large volume in comparison with the volume of water in storage in the upper 50 feet of the unit, and it is obvious that the average length of stay of a quantum of ground water is short; the turnover is great. Hydraulic gradients are steep; the distance from point of recharge to point of discharge is small. Most of the water enters and leaves the aquifer in weeks or months. In contrast, hydraulic gradients in the alluvium are low, and the distance from point of recharge to discharge may be farther.

Annual Ground-Water Withdrawal

Ground-water withdrawal (table 63), based on 1967 data and projected to 1970, amounts to about 300,000 acre-feet a year. This is a very small percentage of annual natural recharge and discharge. Practically all the pumpage is from the alluvial and glacial deposits and amounts to about 3 percent of the estimated natural discharge from that unit.

Table 63 - Estimated Ground-Water Withdrawal and Consumptive Use, Subregion 1, 1970

	Ac-ft per year; all quantities in thousands			
	Idaho	Montana	Washington	Total
Irrigation				
Acres irrigated	11.0	16.5	18.0	45.0
Withdrawal	33.0	50.0	54.0	137.0
Consumptive use	17.0	25.0	27.0	69.0
Industrial[1/]				
Withdrawal	8.6	20.0	2.6	31.0
Consumptive use[2/]	.4	1.0	.1	1.5
Public Supplies				
Persons served	23.0	56.0	270.0	350.0
Withdrawal	5.5	14.0	90.0	110.0
Consumptive use[3/]	1.1	2.8	18.0	22.0
Rural-Donestic				
Persons served	23.0	95.0	60.0	178.0
Withdrawal[4/]	2.6	10.6	6.7	20.0
Consumptive use[5/]	1.3	5.3	3.3	10.0
Stock				
Withdrawal and consumptive use[6/]	.12	1.3	.46	1.9
TOTAL WITHDRAWAL (rounded)				300.0
TOTAL CONSUMPTIVE USE (rounded)				100.0

1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

Chemical Quality of Water

Generally, the water is of good to excellent quality throughout the subregion. Dissolved solids commonly are less than 200 mg/l in water from the alluvial deposits (Qg), 250 mg/l in water from the basalt of the Columbia River Group (Tcr), and 500 mg/l in water from the sedimentary rocks (Ts). The water is soft to hard; hardness generally ranges between 50 and 150 mg/l. Boron and flouride are low, and the SAR (sodium adsorption ratio) is less than 1, except for water from some wells several hundred feet deep in the sedimentary strata which may have SAR's of 10 to 15. Silica concentrations in water from the basalt usually are 40 to 60 mg/l; water from the alluvial deposits has much lower silica concentrations. Iron causes problems only at a few places.

No data are available regarding the chemical character of water from the Tertiary volcanic rocks (Tv). It probably has chemical characteristics similar to those of water from basalt of the Columbia River Group.

Most of the water utilized from the pre-Tertiary rocks is obtained from springs, or from wells of shallow depth. That water is usually soft to moderately hard and has low concentrations of dissolved solids. Water from wells several hundred feet deep, or from springs rising from deep-seated sources, may be more highly mineralized.

Temperatures generally range from 45°F. to 60°F., but may be higher in deep wells.

Present Use and Future Availability

Estimates of present use of ground water are based on data for 1965 to 1967, projected to 1970. Projection of public supply, domestic, and industrial use was on the basis of estimated population growth. Irrigation use was projected on the basis of past rates of increase, modified for special situations. Ground-water withdrawal and the quantity used consumptively are given in table 63. Because some of the return may be into streams, net ground-water withdrawal may exceed consumptive use. However, in most areas where significant quantities of ground water are withdrawn, a large part of the water not used consumptively returns to the ground. Practically all the water withdrawn is from the alluvial aquifer unit (Qg).

Total annual ground-water withdrawal is about 300 thousand acre-feet and consumptive use is about 100 thousand acre-feet a year. Net withdrawal of ground water by pumping is somewhat greater than consumptive use but probably does not exceed 150 thousand

acre-feet annually in comparison with an annual natural discharge from the alluvial-aquifer unit of about 10 million acre-feet a year. It is obvious that additional large supplies are available from this aquifer unit. Additional large-scale development would decrease the minimum flows of some rivers to some extent. However, replenishment of the aquifers would be largely during periods of high runoff in the late winter and spring.

A few wells obtain moderate supplies from the Tertiary sedimentary strata (Ts), but generally little exploration for ground water has been done in this unit. The outcrop area of the unit in Subregion 1 is about 840 square miles. In addition, it underlies large areas shown on the aquifer unit map, figure 116, as alluvial-aquifer unit (Qg). Although the Tertiary sediments are predominantly fine grained, there may be sufficient coarser grained strata to serve as aquifers at many places. The unit generally is several hundred to more than a thousand feet thick. It is possible that it could be an important source of ground-water supply in some places. The basalt of the Columbia River Group (Tcr) is an important aquifer unit in eastern Washington and eastern Oregon but has not been developed extensively for large supplies in Subregion 1. There probably are a number of places where the unit is thick enough to yield moderate to large supplies.

Artificial Recharge

So far as is known, no artificial recharging is done in Subregion 1. Although additional space for storage is available in the alluvial and glacial deposits, under present conditions little benefit would be gained by artificial recharge except, perhaps, for localized and special situations.

Water Rights

Idaho

Most of the subregion in Idaho is mountainous and ground-water development has been almost exclusively limited to the stream valleys. Development has not been extensive, and interference between ground-water rights has been very limited. In general, when applications are filed to appropriate the ground water, they are approved without protest. Quantitative figures relating to the water rights for the entire Idaho portion of the subregion are not available.

Some ground-water development has lead to the establishing of water rights in the stream valleys near St. Maries, Sandpoint, and Bonners Ferry.

The most extensive development in the subregion has occurred north of Coeur d'Alene in the Rathdrum Prairie. The aquifers in the Prairie yield copious amounts of ground water to properly constructed wells and many of the land owners have found that irrigation does increase the productiveness of the land. There are now 68 water rights on file to divert a total of 191.34 second feet of water from the Rathdrum Prairie aquifer.

Washington

In that part of the Clark Fork-Kootenai-Spokane Subregion located in the State of Washington, essentially Water Resource Inventory Areas 54 through 57, and 62 (figure 27), a total of 444 active ground water right appropriation and declaration records, in permit and certificate stages, were on file with the Department of Water Resources as of September 30, 1966. Prime rights in this area allow summer-period consumptive withdrawals totaling 588,124 gpm (1,310 cfs). A total of 2,003 gpm has been appropriated under supplemental rights.

Prime water right quantities for the more important use categories and total actual ground-water right quantities are listed in table 64, according to Water Resource Inventory Areas as defined by the State of Washington, Department of Water Resources (Regional Summary). More detailed information about specific rights can be obtained from the Department of Water Resources.

Table 64 - Summary of Ground-Water Rights in the Washington Part of Subregion 1, 1966

Basin No.[1]	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total[2]
54	Lower Spokane	59,820	25,490	5,922	1,648	-	1,450	89,388
55	Little Spokane	43,350	26,466	18,290	18,420	505	870	99,956
56	Hangman Creek	4,750	10,699	4,957	2,420	-	-	16,506
57	Middle Spokane	142,800	197,756	207,779	106,697	-	1,403	381,899
62	Pend Oreille	-	365	150	-	-	-	375
TOTAL		250,720	260,776	237,098	129,185	505	3,723	588,124

1/ Water Resource Inventory Area number as shown in figure 27.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed, and (2) water right quantities that are common to two or more uses are listed under each applicable-use category.

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

In Subregion 1, ground water discharges to streams practically everywhere in the highlands and mountains where the pre-Tertiary (pT) rocks are at or near the surface. Streams that drain the mountains generally derive one-fifth to one-third of their average discharge from ground water. The ratio of ground water to surface water generally ranges from a few percent during periods of high flow to 100 percent during periods of low flow. During a

120-day period of no recharge, ground-water discharge declines to 10 or 20 percent of the discharge at the beginning of the period, indicating that most of the water in the pre-Tertiary aquifer unit is in shallow, short-term storage. Ground water in this aquifer unit is almost everywhere effluent throughout the year.

Most of the streams that drain the highlands and mountains lose part of their flow to the alluvial-aquifer unit where they enter the lowlands. The alluvial-aquifer unit also is recharged with large volumes of surface water that are diverted for irrigation of lowland areas during the late spring and summer. In the northern part of the Deer Lodge Valley, more than 50 percent of the irrigation diversions become ground-water recharge. (63)

Ground water in the alluvial-aquifer unit, in turn, is effluent to the major streams in their down-valley reaches during most of the year. For short periods during flood stages, some water goes into bank storage in the larger valleys. There is generally little information on the importance of bank storage, but in the Bitterroot Valley, the bank-storage component of the ground-water component of discharge of Clark Fork is reportedly of minor importance. (131)

The Rathdrum Prairie-Spokane Valley is a special situation in that the water level in the alluvial and glacial deposits is far below surface-water levels between Pend Oreille Lake and a point a few miles east of Spokane. Underflow through the alluvium between the Idaho-Washington State line and that point is about 1,000 cfs. The entire underflow enters the Spokane River before it joins the Columbia River. Because the aquifer is extensive, thick, porous, and permeable, and the distance from point of recharge to point of discharge is several to several tens of miles, the rate of ground-water recession is slow. Rorabaugh and Simons (131) related discharge from the aquifer into the Post Falls-Spokane reach of the Spokane River to the water level in well 53N-4W-24661, and concluded that, with little or no recharge from precipitation, it would take nearly 3 years for the water level to drop from the high of record (equivalent to a ground-water outflow of about 1,020 cfs) to the low of record (equivalent to about 730 cfs). This is a recession rate of less than 10 cfs per month, and is in sharp contrast to the rapid flow-recession rate of streams draining pre-Tertiary rocks. The contrast is illustrated in figure 119 by partial hydrographs for the St. Joe River (drains pre-Tertiary unit), the St. Maries River (drains pre-Tertiary and basalt units), and the Little Spokane River (drains chiefly the alluvial aquifer unit).

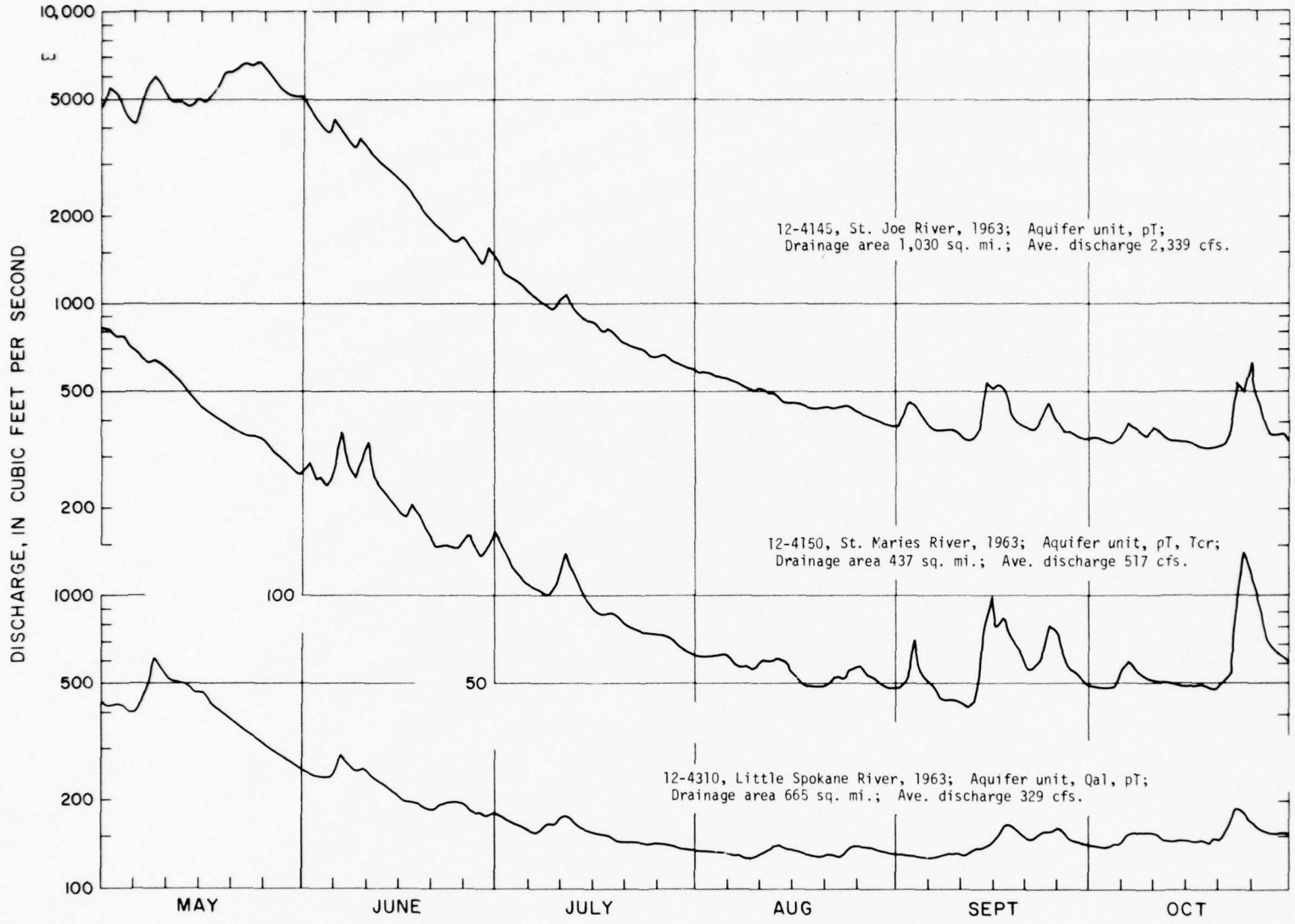
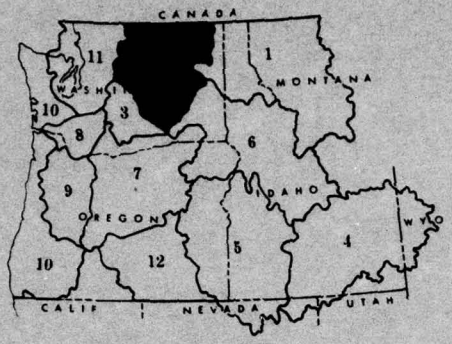


Figure 119 Hydrographs showing low-flow characteristics of selected streams



LOCATION MAP

SUBREGION 2

SUBREGION 2, UPPER COLUMBIA

HYDROLOGIC FRAMEWORK

The upper Columbia Subregion lies totally within the State of Washington and is bounded on the north by Canada, on the west by the Cascade Range and Wenatchee Mountains, on the southwest and southeast by ranges of low hills and on the east by the Spokane and Pend Oreille River watersheds. Elevations range from 340 feet above sea level near the confluence of the Snake and Columbia Rivers to 3,000 feet in the Waterville Plateau and 5,000 to 8,000 feet at the crest of the Cascades and on north-south ridges along the Canadian border.

The subregion covers 22,451 square miles, of which 450 square miles are water and 22,001 are land, altogether amounting to about 8 percent of the regional area.

Broadly characterized, the Geologic structure consists of igneous rocks in the Cascade Range and the Columbia Basin. Glacial action has altered the area. The valley bottoms and lower terraces were formed from alluvial or glacial deposits. A large area of the Columbia Basin is covered by deep loessal soils.

The major stream is the Columbia River, which passes through the subregion. The Methow, Chelan, and Wenatchee Rivers, which flow from the Cascade Range, contribute most of the water generated within the area. The Colville River, which heads in the northeast part of the subregion, has an annual flow averaging only about 300 cfs. The Similkameen, Okanogan, and Kettle Rivers also contribute a sizable quantity of water, but these streams originate outside the subregion. The Spokane River is also a major contributor, but lies entirely outside the subregion. The Columbia Basin portion of the subregion is quite arid and streamflow from this area is small, the major stream being Crab Creek, which averages less than 100 cfs at Irby.

Discharge generated within the subregion is principally spring runoff caused by snowmelt. In winter months, heavy rainfall accompanied by warming southwesterly wind occasionally causes snowmelt which produces high runoff.

Water use in the subregion is increasing at a rapid rate, with the largest increase being for irrigation diversions to the Columbia Basin Project. These diversions, which began in 1951, served approximately 516,000 acres in 1970.

CLIMATE

The climate varies from desert conditions over some of the lower basin to a moist alpine type in the higher elevations of the Cascades and has both continental and maritime characteristics. Topography, prevailing westerly winds, the path of storm systems from the Pacific Ocean, and the distance and direction from the ocean all have an influence on the climate.

The Cascade Range, athwart the course of the prevailing westerly winds, forms a barrier to the easterly movement of moist air from over the ocean. To the east and north, the Rocky Mountains and ranges in southern British Columbia generally shield this subregion from winter season cold air masses moving southward across Canada. However, the north-south valleys between ranges near the border permit some infiltration of arctic air. Occasionally, cold air will spill over the Rockies and cover all of eastern Washington.

With the prevailing flow of air and movement of weather systems across this subregion from west to east, most of the air masses have spent several days over the Pacific Ocean before reaching land. The surface of the ocean is warmer in winter and cooler in summer than the land, thus the maritime air has a moderating influence throughout the year. During late spring and summer, the prevailing flow of air is from the northwest and west. Warming and drying as it moves across the state results in a dry season beginning in May and reaching a peak in July and August. In late fall and winter, the prevailing flow of air is from the southwest. This air is moist and near the surface temperature of the ocean. As it moves inland and rises along the windward slope of the Cascades, the temperature decreases with increase in elevation. This orographic lifting results in heavy precipitation along the western slope and near the summit. Air descending along the leeward slope is warmed by compression, resulting in a sharp decrease in precipitation eastward from the summit.

Precipitation

A sharp reduction in precipitation as the elevation decreases eastward from the summit of the Cascade Range can be seen. For example, within a distance of 20 miles, annual precipitation decreases from 76 inches at Stevens Pass (elevation 4,000 feet) to 24 inches at Leavenworth (elevation 1,100 feet). Within the next 15 miles, it drops to 9 inches at Wenatchee (elevation 934 feet). Across the Okanogan Highlands, annual amounts range from 12 to 15 inches in the valleys increasing to 30 inches on the windward slopes of the higher ridges. Over most of the Columbia Basin portion of the subregion, where elevations range from 500 to 1,500 feet above sea level, annual precipitation varies from

7 to 12 inches. Approximately 50 percent of the annual precipitation falls in the 4 months, October through January, and 75 percent from October through March. The total precipitation for the two driest months, July and August, is from 5 to 10 percent of the annual (table 65 and figure 120). In the drier areas, measurable precipitation is recorded on 1 to 3 days each month in summer, 4 to 7 days in spring and fall, and 8 to 12 days in winter. In the mountains, the number varies from 4 to 6 in summer, 7 to 12 in spring and fall, and 20 to 25 in winter.

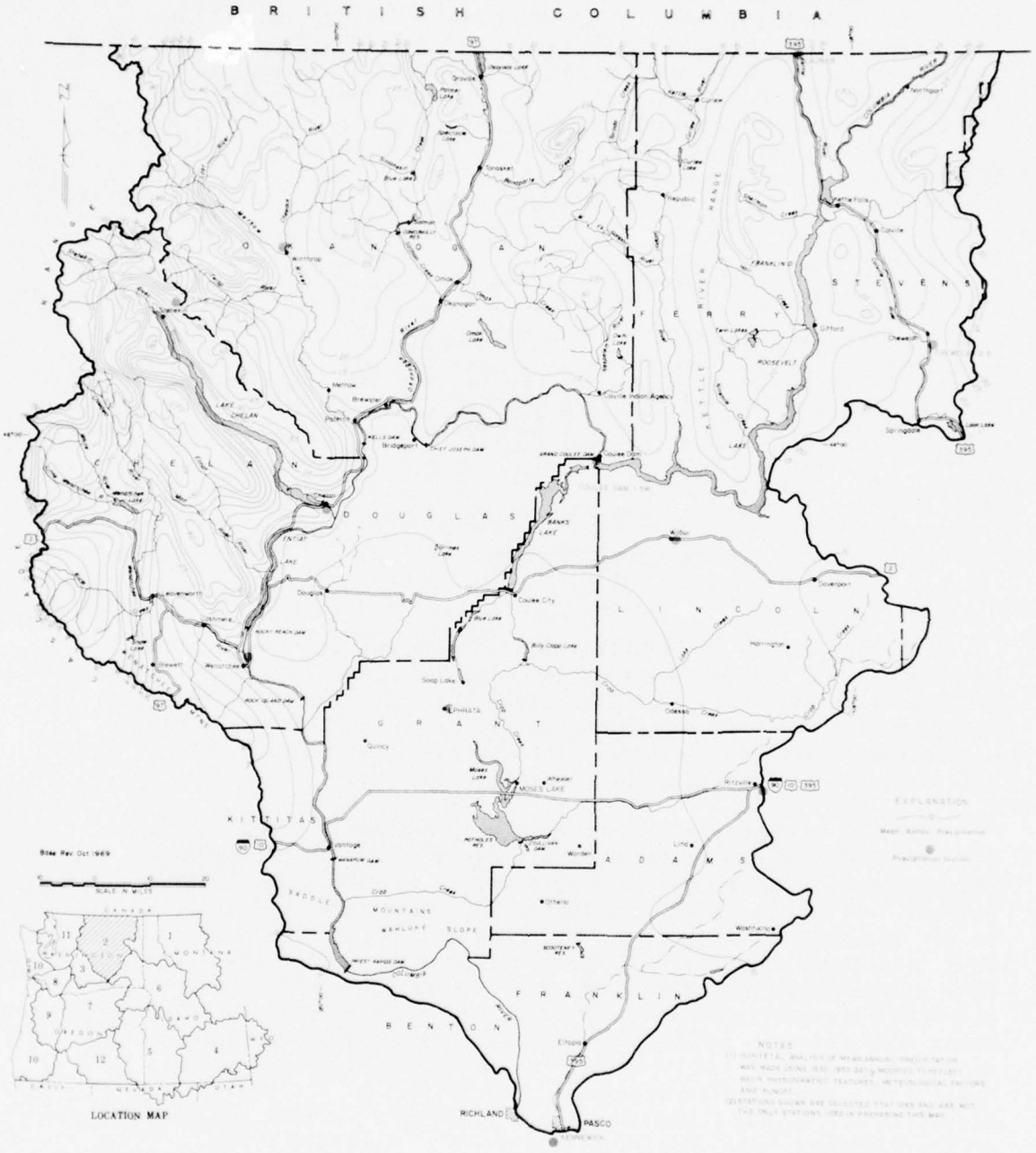
Table 65. Average Monthly and Annual Precipitation (inches), Upper Columbia Subregion, 1931-1960

Station	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Chelan	1,120	1.40	1.10	0.89	0.72	0.86	1.07	0.24	0.31	0.56	0.98	1.50	1.60	11.23
Chewelah 2S	1,635	2.52	1.83	1.70	1.29	1.67	1.58	0.64	0.59	1.08	1.85	2.34	2.75	19.82
Ephrata	1,275	1.05	0.74	0.67	0.56	0.72	0.92	0.20	0.25	0.46	0.77	0.98	1.10	8.42
Coulee Dam 1SW[1/]	1,702	1.18	0.97	0.71	0.80	1.19	1.23	0.38	0.43	0.57	0.89	1.19	1.12	10.66
Laurier	1,644	2.11	1.52	1.35	1.32	1.68	2.28	0.98	0.95	1.11	1.79	1.95	2.22	19.26
Ritzville	1,825	1.44	1.04	1.01	0.74	0.94	1.15	0.29	0.33	0.65	1.19	1.38	1.51	11.67
Stehekin 3NW	1,150	5.28	4.34	3.01	1.19	1.00	0.90	0.39	0.46	1.22	3.38	5.88	6.75	33.80
Kennewick	392	1.05	0.82	0.56	0.48	0.54	0.63	0.17	0.14	0.33	0.73	0.95	1.09	7.49
Wenatchee	634	1.16	0.98	0.67	0.47	0.65	0.91	0.11	0.37	0.47	0.73	1.14	1.34	9.00
Wilbur	2,163	1.66	1.13	1.03	0.83	1.21	1.20	0.41	0.35	0.70	1.25	1.57	1.59	12.93
Winthrop	1,755	2.04	1.59	0.89	0.67	1.01	1.23	0.52	0.48	0.66	1.02	1.94	2.50	14.55

1/ Period may be longer or shorter than 30 year normal.

Figure 120 is an isohyetal map of mean annual precipitation prepared by the Weather Bureau River Forecast Center, Portland, Oregon, using climatological data (1930-57) and information derived from correlations with physiographic factors. Table 65 presents precipitation data for selected stations which are not the only stations used in preparing the isohyetal map.

In an average winter, snowfall ranges from 10 to 20 inches over lower elevations of the Columbia Basin, 30 to 70 inches on the Waterville Plateau and northern valleys, 75 to 150 inches in the foothills of the Cascades, and 300 to 500 inches near the crest. In the southern section, snow remains on the ground from a few days to 6 weeks with 5 to 15 inches accumulating. The Waterville Plateau and northern valleys are usually covered with snow from mid-December until late February or March. Depths in these areas range from 10 to 30 inches. In the higher mountains, snow can be expected in October and to remain on the ground from mid-November until June. Snow depths may reach 6 to 10 feet on the higher ridges of the Okanogan Highlands, and 10 to 20 feet near the summit of the Cascades. The density of the snowpack increases from approximately 25 percent water equivalent in early winter to 45 percent in March.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL PRECIPITATION IN INCHES

UPPER COLUMBIA SUBREGION 2

1968

FIGURE 120

Temperature

During the warmest summer months, afternoon temperatures over the lower elevations range from 80° to 95°F., reaching 100°F. or higher on a few days. Extreme temperatures between 105° and 112°F. have been recorded at most reporting stations, with the record high being 118°F. at Wahluke. Minimum summer temperatures are in the 50's and 60's. In the mountains, maximums are in the 60's and 70's, reaching 80° or higher on a few days, and minimums are in the 40's and lower 50's. The growing season in agricultural areas varies from approximately 130 days in northern valleys to 180 days at the southern section of the subregion (table 66 and figure 120).

In winter, weather systems moving eastward from the Pacific and outbreaks of cold air from Canada produce frequent changes. Minor outbreaks of arctic air occur frequently; however, they are usually of short duration. Occasionally, very cold air will cover the entire area and usually low temperatures will continue for 2 weeks or longer. During an average winter, maximums range from 25° to 35°F. in northern valleys and 30° to 40°F. in southern areas. Minimums are from 5° to 15°F. in the colder areas and 20° to 30°F. in the warmer. Below zero readings can be expected on a few nights and -15° to -25°F. have been recorded at most stations.

Wind

Topography has an influence on the prevailing direction of the wind. In general, the wind is from the west or southwest most of the year. However, in winter the frequency of winds from the northeast and north over the northern half of this subregion may equal the occurrences of westerly winds. High velocities throughout the year are from the west or southwest. Extreme winds can be expected to exceed 50 mph once in 2 years and 60 to 70 mph once in 50 years.

Evaporation

Annual evaporation from a class A pan is estimated at 50 to 60 inches in the warmest areas and 30 to 40 inches on the higher slopes. Monthly amounts in the agricultural areas are 2 to 5 inches in spring and fall, and 7 to 12 inches in summer. Annual loss of water by evaporation from lakes and reservoirs is estimated at 25 inches in the mountains and 40 inches in the Columbia Basin.

Table 66 - Average and Extreme Temperatures (°F.), Subregion 2, Upper Columbia

Station	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Chelan	Av. Max.	30.4	37.2	49.8	62.0	72.7	77.7	86.4	85.0	74.4	61.0	43.9	34.7	59.6
	Av. Min.	19.8	23.6	31.7	39.7	47.6	54.1	60.2	59.2	50.5	41.0	31.3	25.0	40.3
	Mean	25.5	30.4	40.6	50.6	59.4	65.6	72.9	71.2	62.8	50.9	37.3	30.3	49.8
	Highest	59	61	74	86	95	102	106	103	95	85	65	65	106
	Lowest	-14	-15	4	23	28	36	43	42	29	10	-3	-12	-15
Chewelah 2S	Av. Max.	31.7	38.8	49.4	61.7	71.3	76.9	87.3	86.3	76.9	61.7	42.6	34.9	59.5
	Av. Min.	15.0	18.3	27.1	32.6	39.2	44.6	45.9	42.4	37.6	31.7	26.6	21.9	31.9
	Mean	23.3	28.5	38.2	47.2	55.2	60.7	66.6	64.4	57.3	46.7	34.6	28.4	45.9
	Highest	55	61	74	89	96	98	107	103	101	88	69	58	107
	Lowest	-38	-38	-12	12	16	26	32	28	16	2	-15	-27	-38
Ephrata	Av. Max.	33.0	41.0	54.0	65.6	74.9	81.6	90.9	88.5	78.9	65.3	47.0	36.5	63.1
	Av. Min.	19.7	25.4	33.1	40.3	48.8	55.3	62.5	60.5	52.0	42.3	31.0	24.5	41.3
	Mean	27.5	33.3	43.4	53.2	62.1	68.5	76.5	74.5	66.5	53.8	38.8	31.6	52.5
	Highest	61	68	77	93	101	106	113	107	102	90	78	64	113
	Lowest	-17	-23	3	16	28	36	42	30	20	12	0	-12	-23
Coulee Dam 1SW[1/]	Av. Max.	30.8	38.1	50.4	62.5	72.3	78.1	88.6	86.2	77.9	62.1	43.1	35.6	60.5
	Av. Min.	20.6	24.5	31.2	38.6	46.6	52.3	57.9	56.5	50.8	41.1	30.9	26.2	39.8
	Mean [1/]	25.7	31.3	40.8	50.6	59.5	65.2	73.3	71.4	64.4	51.6	37.0	30.9	50.2
	Highest	54	60	74	92	99	105	113	106	104	90	62	58	113
	Lowest	-17	-15	0	20	27	38	43	38	34	12	1	-2	-17
Laurier	Av. Max.	29.4	37.2	48.9	62.3	72.0	78.1	88.3	86.2	75.6	58.7	40.5	31.9	59.1
	Av. Min.	14.4	17.6	25.2	32.7	40.0	46.5	50.3	48.6	41.6	33.6	26.5	19.5	33.0
	Mean	22.7	27.6	36.9	47.9	56.8	62.4	69.4	67.4	59.2	46.6	33.6	26.9	46.5
	Highest	53	58	73	92	102	103	109	105	105	85	63	56	109
	Lowest	-32	-30	-13	11	16	28	34	31	18	6	-9	-26	-32
Ritzville	Av. Max.	33.2	39.8	51.2	62.1	71.7	78.9	89.3	87.0	77.1	63.3	45.3	36.2	61.3
	Av. Min.	19.8	24.3	30.2	35.1	41.6	47.5	53.2	52.1	45.9	37.2	28.7	23.7	36.6
	Mean	27.0	32.1	40.6	48.8	56.8	63.1	71.1	69.3	62.1	50.6	36.9	31.2	49.1
	Highest	60	62	77	92	99	108	110	106	101	93	67	62	110
	Lowest	-23	-24	3	11	22	29	33	35	20	5	-10	-21	-24
Stehekin 3NW	Av. Max.	33.5	39.6	47.5	59.4	68.2	74.0	82.1	80.1	70.9	57.7	43.0	35.0	57.6
	Av. Min.	21.6	24.0	28.5	34.8	41.6	47.5	52.1	50.7	43.8	36.2	29.6	25.3	36.3
	Mean	27.4	30.8	37.7	47.1	55.0	60.5	66.5	64.8	57.2	46.6	36.0	30.8	46.7
	Highest	54	63	69	84	92	97	103	98	93	84	67	62	103
	Lowest	-18	-16	-5	19	25	30	36	35	22	16	0	-11	-18
Kennewick	Av. Max.	38.9	46.6	58.4	68.6	76.6	83.4	92.0	89.1	79.2	66.6	50.7	41.7	66.0
	Av. Min.	24.3	29.1	34.6	39.7	47.5	53.4	59.1	56.8	49.0	40.7	32.8	28.0	41.3
	Mean	31.8	37.5	46.1	54.5	62.3	68.3	75.1	72.4	64.6	53.7	41.2	36.0	53.6
	Highest	74	74	88	95	105	108	115	115	102	89	78	71	115
	Lowest	-27	-23	10	18	26	37	38	37	21	14	-12	-29	-29
Wenatchee	Av. Max.	33.0	40.4	54.2	65.5	73.6	79.8	88.2	86.9	77.7	63.7	46.4	36.6	62.2
	Av. Min.	18.3	22.2	30.7	38.3	46.2	53.0	58.5	56.2	47.8	37.8	29.1	23.7	38.5
	Mean	26.2	31.5	42.3	52.2	60.5	66.5	73.4	71.5	63.5	51.1	37.7	31.1	50.6
	Highest	58	66	81	92	98	106	110	106	98	90	71	63	110
	Lowest	-29	-18	4	20	27	35	40	40	22	20	1	-18	-29
Wilbur	Av. Max.	30.6	37.3	49.1	60.6	69.2	76.1	85.1	83.5	74.1	61.3	43.4	34.2	58.7
	Av. Min.	16.3	20.2	27.5	33.1	39.3	44.5	48.5	47.3	41.2	33.8	27.0	21.4	33.3
	Mean	24.5	29.2	38.2	47.0	55.0	60.6	67.6	65.6	58.6	47.9	35.3	29.1	46.6
	Highest	65	58	75	90	96	106	110	104	99	87	68	56	110
	Lowest	-27	-30	-10	10	19	25	25	25	14	1	-15	-22	-30

1/ Period may be longer or shorter than 30-year normal
Temperature extremes are for period of record through 1960

Evapotranspiration

Potential evapotranspiration is 25 to 30 inches in the warmest areas and 15 to 18 inches in the mountains. Assuming that soils have a water-storage capacity of 6 inches, computations have been made of the actual evapotranspiration which occurs with average temperatures and precipitation. Annual amounts are 7 to 10 inches in the Columbia Basin area and 12 to 16 inches in the higher elevations. In general, potential evapotranspiration exceeds actual evapotranspiration by 15 to 20 inches in the lower elevations.

Storms

Rainfall is frequently associated with thunderstorms. Occasionally rather intense thunderstorms and damaging hail are reported. Thunderstorms occur most frequently in the mountainous areas.

Sunshine

The loss of heat by radiation at night in the colder months and moist air reaching the inland basin results in considerable fog and low clouds. The number of clear or only partly cloudy days each month is 4 to 8 in winter, 10 to 20 in spring and fall, and 20 to 25 in summer. It is estimated the agricultural areas receive 20 percent of the possible sunshine in winter, 40 to 60 percent in spring and fall, and 70 to 80 percent in summer.

SURFACE WATER

The principal streams in the subregion are the Columbia, Kettle, Similkameen, and Okanogan Rivers draining from Canada; the Methow, Chelan, and Wenatchee Rivers draining the east slope of the Cascade Range; and the Colville River originating in the Selkirk Mountains. The Columbia River is extensively developed for hydroelectric power, and at Hanford there is a large nuclear power reactor producing thermal power. Only two of the tributaries, the Colville River and the Chelan River, have developments for hydroelectric power.

Quantity

The average annual outflow from the subregion is 114,800 cfs. Inflow from the Columbia River in Canada averages about 95,800 cfs. The difference, 19,000 cfs annually, would be reduced further by the inflow to the subregion of the Okanogan, Similkameen, Kettle, and

Spokane Rivers, which originate outside the subregion. Flow generated within the subregion is about 5,300 cfs (3.8 million acre-feet annually). This averages 0.24 cfs per square mile, one of the lowest rates in the subregion.

Present Utilization

The greatest consumptive use of water in the subregion is by irrigation, and the greatest single diversion is from Franklin D. Roosevelt Lake at Grand Coulee Dam, which averages 3,680 cfs for the irrigation of 516,000 acres on the Columbia Basin project. The rediversion and reuse of return flows and large losses to ground water within the area result in relatively little surface runoff (only about 100 cfs) return to Columbia River. There is also irrigation in the valleys of the rivers which enter the Columbia River, but the total of all these would not compare with that on the Columbia Basin project. A vast quantity of water is used for the production of hydroelectric power. Seven major powerplants are located in the reach of the Columbia River within Subregion 2.

Stream Management

Competition for water among the various users necessitates efficient stream management. Storage and release, diversions, conservation, legal constraints, etc., all are a part of the water management system.

Impoundments Reservoirs in the Upper Columbia Subregion having a total capacity of 5,000 acre-feet or more are listed in table 67. The uses listed are those which are now considered prime functions of the reservoirs but may not represent either the specific considerations used in planning the reservoirs or a complete list of functions served. Most of the reservoirs provide recreational use, and several of them also provide some flood control.

Diversions The largest diversions for consumptive use of water are for irrigation. These diversions are generally confined to the irrigation season April-September, peaking up to highest diversion during midsummer whenever adequate flow is available to meet the requirements.

Many large diversions for power are made within the subregion. These diversions are nonconsumptive; the water is returned to the stream within a short distance from the diversion.

Table 67 - Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More

Name	Stream	Total Storage (acre-feet)	Total Storage (acre-feet)	Area (acres)	Purpose[4]
Rufus Woods Lake (Chief Joseph)	Columbia R.	518,000	114,000	7,800	P
Conconully	Salmon Cr.	13,000	13,000	420	IR
Conconully Lake[1]	N.F. Salmon Cr.	10,500	10,500	313	IR
Franklin D. Roosevelt Lake	Columbia R.	9,562,000	5,232,000	83,000	FIP
Banks Lake[1]	Columbia R.	1,275,100	761,800	27,000	IR
Lake Chelan[2]	Chelan R.	677,365	677,365	31,975	PR
Billy Clapp Lake[1]	Columbia R.	65,000	1,000	--	I
Owhi	Little Nespelem R.	5,250	5,250	540	I
Potholes[1]	Columbia R. & Lower Crab Cr.	525,100	379,500	32,400	IR
Priest Rapids	Columbia R.	200,000	44,800[3]	7,200	FPR
Rock Island	Columbia R.	--	8,600[3]	3,470	P
Entiat Lake (Rocky Reach)	Columbia R.	390,000	64,300[3]	9,800	P
Scooteney[1]	Columbia R.	15,250	6,750	--	I
Snow Lakes	Snow Cr.	16,500	12,500	184	CI
Twin Lakes	Stranger Cr.	15,124	15,124	1,892	I
Wanapum	Columbia R.	486,000	160,800	14,610	FPR
Wells	Columbia R.	300,000	70,700[3]	9,700	P

1/ Offstream.
2/ Capacity between elevations 1,079 and 1,100 feet, regulation allowed by FPC.
3/ Pondage available with some minimum flow.
4/ P-power, F-flood control, R-recreation, I-irrigation, C-fish and wildlife conservation.

Channel Modification Stream modification is limited mainly to local bank protection or levee construction as flood control measures. The major levee works are around the cities of Richland and Pasco in the extreme southern portion of the subregion. Prior to the existence of the great number of dams on the Columbia River, some channel clearance was done for navigational purposes. Within the reaches of these dams and reservoirs, the need of channel work for navigational purposes is eliminated on the Columbia River and the lower portion of some of the tributary rivers.

Forecasting Forecasting of runoff and peak flows is developed and used chiefly in flood warning and in the operation of reservoirs for flood control. It also provides a means of assuring a maximum of stored water for power generation and irrigation consistent with other uses.

Constraints There are no interstate compacts or international treaties that are concerned directly with runoff in the Upper Columbia Subregion. There are, however, international treaties and regulations regarding inflow streams which affect the use of the Columbia River within the subregion. The height of Grand Coulee Dam and the size of Franklin D. Roosevelt Lake were limited so that the lake should not increase river water levels in Canada. An international treaty between Canada and the United States (described in

Appendix III, Legal and Administrative Background) in regard to the Columbia River was signed in 1961 providing for cooperative development of the resource and for the distribution of benefits resulting from the treaty storage. This controlled storage will affect the flows and uses within Subregion 2, as compared to the past.

Water Rights

In the Upper Columbia Subregion, consisting essentially of State of Washington Water Resource Inventory Areas 36, 40 through 53, and 58 through 61 (figure 121), a total of 1,483 active surface-water appropriation records, in permit and certificate stages, was on file with the State of Washington, Department of Water Resources, on April 30, 1967. Prime appropriative rights in this area allow summer period diversions totaling about 1,052,000 cfs of which consumptive diversions amount to about 3,000 cfs, partially consumptive diversions are allowed for about 1,000 cfs, and nonconsumptive diversions are permitted for about 1,048,000 cfs; most of the nonconsumptive quantity being associated with hydroelectric powerplants on the Columbia River and major tributaries. A total of 161 cfs has been appropriated under supplemental rights of which 146 cfs are used consumptively and 15 cfs are partially consumptive to the resource.

Under various decrees in this subregion a total of 916 adjudicated surface water rights has been granted with diversion rates totaling 2,180 cfs. Of this amount, 1,160 cfs have a consumptive effect on the resource, 1,020 cfs are partially consumptive and less than 1 cfs is used nonconsumptively. Supplemental adjudicated rights have been granted for a total of 2 cfs in this area.

Reservoir storage rights obtained through the appropriative procedure permit a total annual retention of 2,320,058 acre-feet in the Upper Columbia Subregion. Storage rights obtained through adjudication provide for a total of 317,358 acre-feet per year.

Prime water right quantities for the more important use categories and total actual surface water right quantities are presented in table 68 according to Water Resource Inventory Areas as defined by the State of Washington, Department of Water Resources (see Regional Summary). More detailed information about specific rights can be obtained from the Department of Water Resources.

Discharge

The base period selected for this study is 1929-1958. Long-term gaging data in the Pacific Northwest indicate that both very

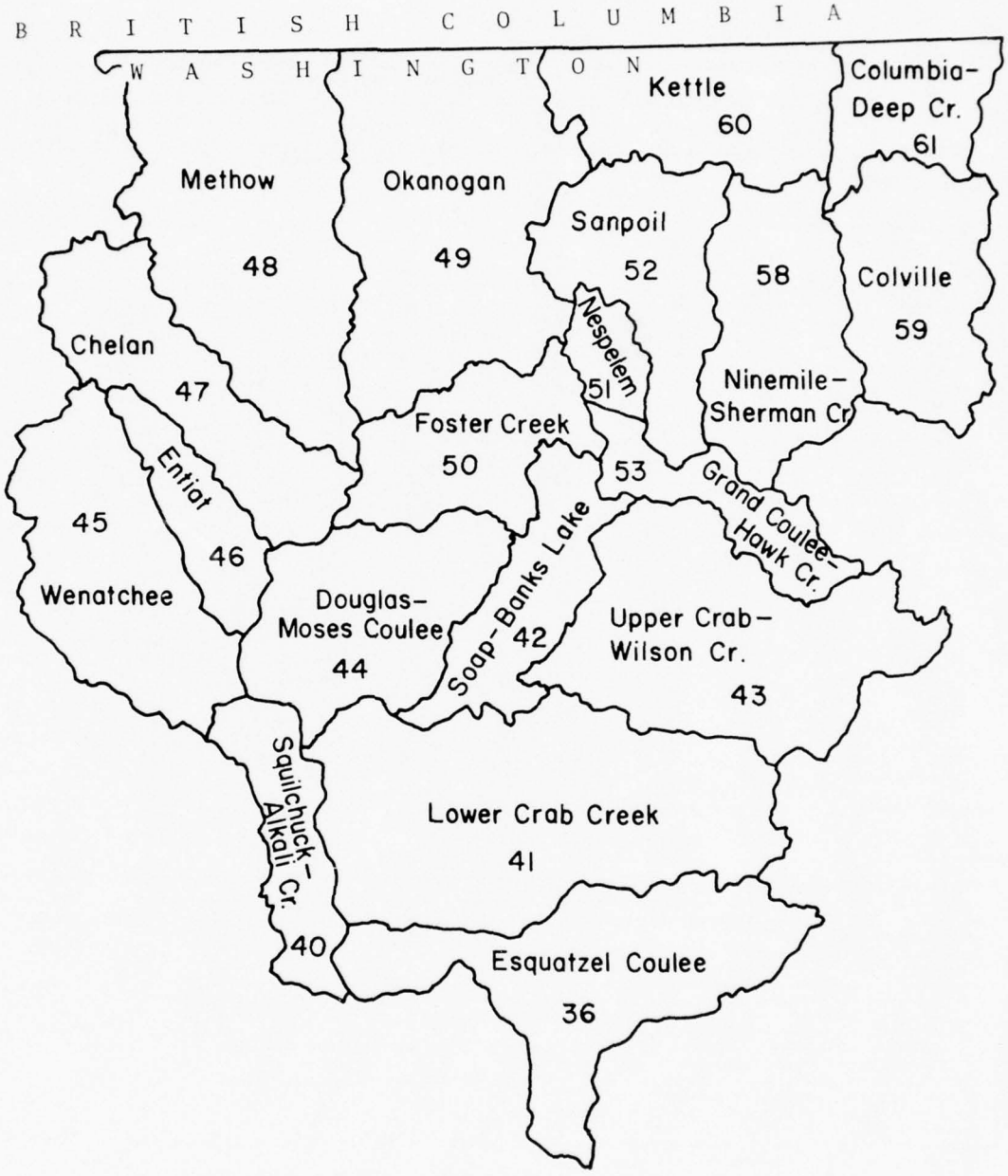


Figure 121 Map showing water resource inventory areas defined by the State of Washington Department of Water Resources.

Table 68 - Surface Water Rights in the Upper Columbia River Subregion, 1967
Prime Water Right Quantities

Basin No. 1/	River Basin	Mun.	Irr.	Ind. & Com. Dom.	Indus. & Cml.	Fish Prop.	Stock	Total 2/	Res. Stge. Rts. Acre-Feet
				Cubic Feet Per Second					
Appropriative Rights									
36	Esquatzel Coulee	- -	8.41	0.04	1.10	- -	- -	258,009.55 3/	200,000 19/
40	Squilchuck-Alkali Cr.	- -	39.96	32.00	43.10	0.20	27.06	371,088.17 4/	656,307 20/
41	Lower Crab Creek	- -	11.53	0.02	- -	- -	- -	11.55	50,000 21/
42	Soap-Banks Lake	1.80	6.82	0.07	2.00	- -	0.51	10.68	- -
43	Upper Crab-Wilson Cr.	- -	1,021.02	0.01	- -	- -	0.15	1,021.03	6,230
44	Douglas-Moses Coulee	6.00	149.03	3.23	0.03	- -	6.03	185,449.14 7/	390,018 22/
45	Wenatchee	11.50	193.48	12.12	44.29 8/	515.04	0.02	792.10 9/	49,030
46	Entiat	1.25	7.30	5.06	4.00	29.50	- -	43.92	80
47	Chelan	2.00	163.00	66.47	22.54	- -	0.25	234,220.26 10/	941,600 23/
48	Methow	- -	264.77	173.29	8.00 12/	21.04	1.99	345.82	6,000
49	Okanogan	1.50	452.37	27.11	1.50	27.45	15.96	488.67	17,273
50	Foster Creek	- -	44.76	0.28	0.45	- -	0.02	45.50	- -
51	Nespelem	- -	0.31	- -	- -	- -	- -	0.31	- -
52	Sanpoil	- -	12.38	2.14	- -	1.25	0.03	14.47	- -
53	Grand Coulee-Hawk Cr.	- -	37.35	1.13	0.08	- -	0.04	38.17	20 24/
58	Ninemile-Sherman Cr.	- -	36.52	10.72	- -	0.24	0.04	51.56 14/	582
59	Colville	- -	142.82	11.71	1.20	17.02	4.44	223.74 16/	918
60	Kettle	- -	57.22	4.99	- -	- -	0.67	57.92	2,000
61	Columbia-Deep Cr.	0.59	22.82	2.74	0.16	- -	0.01	41.01 18/	- -
Appropriative Totals		24.64	2,671.87	353.13	128.45	611.74	57.22	1,051,953.57	2,320,058
Adjudicated Rights									
40	Squilchuck-Alkali Cr.	4.01 5/	107.97	103.96 5/	- -	- -	107.97 5/	108.17	2,406
41	Lower Crab Creek	- -	227.54 6/	227.54 6/	- -	- -	227.54 6/	227.54	314,952 25/
43	Upper Crab-Wilson Cr.	- -	9.32	5.27	- -	- -	0.08	9.40	- -
45	Wenatchee	1.52	101.85	- -	- -	- -	- -	103.37	- -
46	Entiat	- -	4.14	3.77	- -	- -	- -	4.44	- -
47	Chelan	- -	265.33 11/	265.38 11/	0.05	- -	263.59 11/	265.38	- -
48	Methow	- -	70.32	65.49	- -	- -	65.49	70.36	- -
49	Okanogan	0.10	289.74	205.08	- -	- -	199.39	1,290.69 13/	- -
58	Ninemile-Sherman Cr.	- -	21.34	19.06 15/	- -	- -	19.04 15/	21.51	- -
59	Colville	1.00	45.82	1.18	0.51	- -	0.96	68.90 17/	- -
60	Kettle	- -	5.21	0.40	- -	- -	0.40	5.61	- -
61	Columbia-Deep Cr.	- -	0.43	0.11	- -	- -	0.11	0.54	- -
Adjudicated Totals		6.63	1,149.01	897.24	0.56	- -	884.57	2,175.91	317,358
Combined Totals (Approp. & Adjud.)		31.27	3,820.88	1,250.37	129.01	611.74	941.79	1,054,129.48	2,637,416

1/ Water Resource Inventory Area number as shown in figure 121.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed, and (2) water right quantities that are common to two or more uses are listed under each applicable use category.
3/ Includes 258,000.00 cfs for hydroelectric power generation.
4/ Includes 371,001.00 cfs for hydroelectric power generation.
5/ Quantities are common with irrigation use.
6/ The quantities for irrigation, individual and community domestic supply and stock use are all common.
7/ Includes 185,300.00 cfs for hydroelectric power generation.
8/ Includes 18.90 cfs for heat exchange use.
9/ Includes 47.75 cfs for hydroelectric power generation and 500.04 cfs for fish propagation use.
10/ Includes 234,052.11 cfs for hydroelectric power generation.
11/ Nearly all of the quantities for irrigation, individual and community domestic supply and stock use are common.
12/ Includes 7.40 cfs for heat exchange use.
13/ Includes 1,000.00 cfs for hydroelectric power generation.
14/ Includes 13.70 cfs for hydroelectric power generation.
15/ Quantities for individual and community domestic supply are common with quantity for irrigation use.
16/ Include 78.00 cfs for hydroelectric power generation.
17/ Includes 5.00 cfs for hydroelectric power generation and 15.00 cfs for thermo-electric power generation.
18/ Includes 15.34 cfs for hydroelectric power generation.
19/ Quantity represents the storage right for Priest Rapids Pool.
20/ Includes 541,000 acre-feet for Wanapum Pool and 113,700 acre-feet for Rock Island Pool.
21/ Quantity represents the storage right for Moses Lake.
22/ Quantity represents the storage right for Entiat Lake (Rocky Reach Pool).
23/ Includes 640,000 acre-feet in Lake Chelan and 300,000 acre-feet for Wells Pool.
24/ Does not include the storage quantity in Lake Roosevelt.
25/ Includes 310,640 acre-feet for Moses Lake of which 290,400 acre-feet is in an inchoat status.

low and very high monthly and annual flows occurred during the base period.

Within this subregion, two streams, Chelan River at Chelan and Wenatchee River at Peshastin, have base period mean discharges equal to about 97 and 98 percent of their long-term (56 and 32 years) mean. Weather records show that precipitation at Stehekin and at Lake Wenatchee during the base period was about 99 and 102 percent of the long-term (46 and 47 years in 1960) mean. Thus the selected base period provides a representative sample for statistical analysis.

Measurement Facilities Table 69 lists the selected sites and summarizes pertinent data for detailed study in Subregion 2.

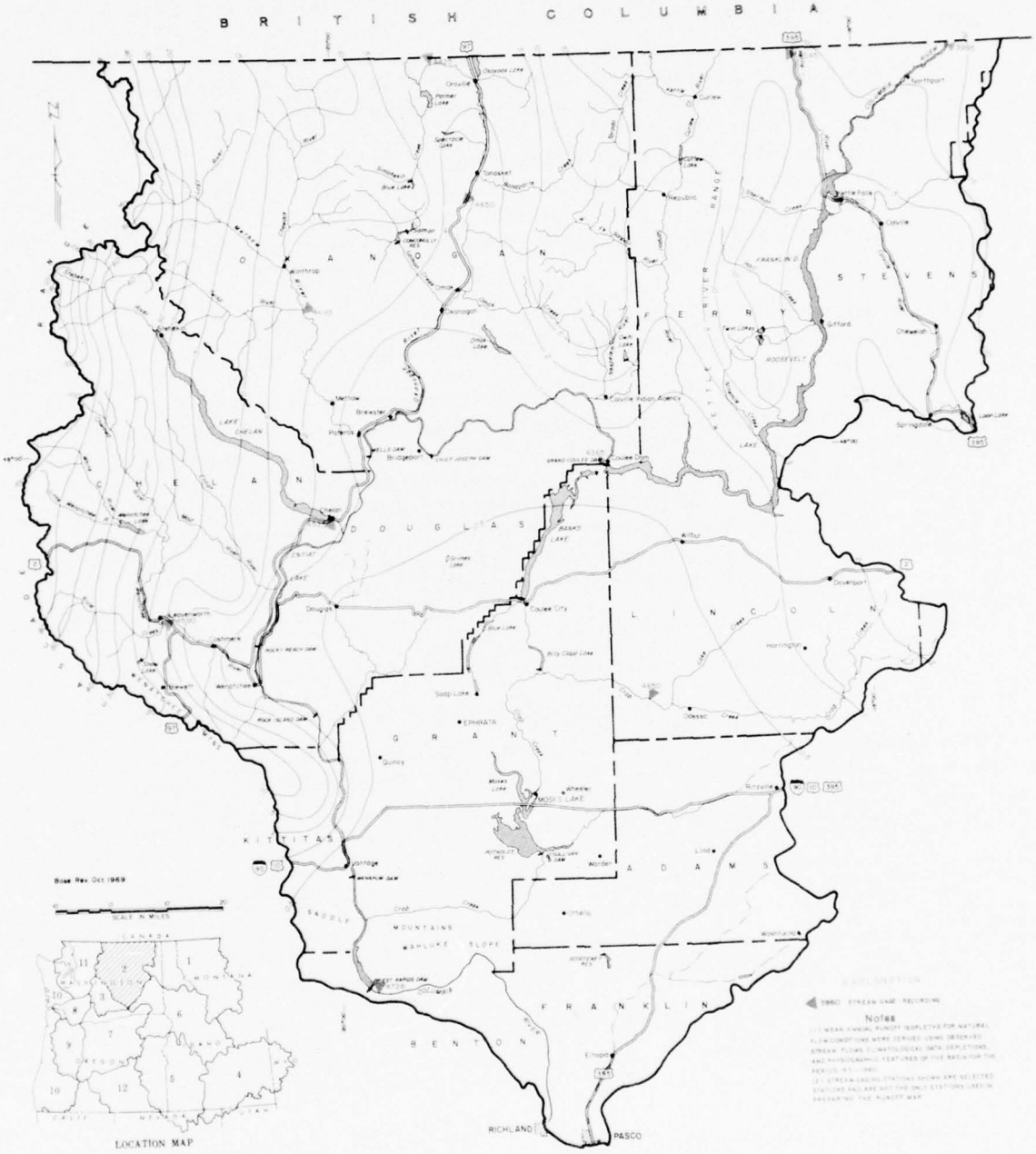
Figure 122 shows the locations of the selected sites, with Geological Survey identification numbers. One selected station, Okanagan River at Okanagan Falls, B. C., is not shown on figure 122. This station is approximately 25 miles north of the station Similkameen River near Nighthawk, Washington. The first two digits of the identification number, part number (12), have been omitted because Subregion 2 lies entirely within the area designated as Part 12, the Washington coast and the Columbia River Basin above Snake River.

Table 69 - Streamflow Summary for Selected Sites, Subregion 2

Stream	Station	Station Number	Gage Datum	Drainage area (sq mi)	Period of Record	Annual Flow 1/ (cfs) Mean	Max.	Min.	Momentary Flow 2/ (cfs) Max.	Min.
Columbia River	International Boundary	3995	0	59,700	37-65	95,800	129,400	72,500	550,100	18,000
Kettle River	Laurier	4045	1,425.5	3,800	29-65	2,852	4,159	1,700	35,000	88
Colville River	Kettle Falls	4090	1,500	1,007	22-65	299	540	75	3,230	1
Columbia River	Grand Coulee Dam	4365	0	74,700	28-65 3/	103,900	142,400	80,300	637,800	14,900
Okanogan	Okanogan Falls	4385	1,092.82	2,650	15-65 4/	549	1,131	52	2,790	5
Similkameen River	Nighthawk	4425	1,137.70	3,550	11-65	2,286	3,948	1,092	38,700	120
Okanogan River	Tonasket	4450	860.78	7,280	29-65	2,894	4,588	1,241	40,900	126
Methow River	Twisp	4495	1,580	1,330	19-62 4/	1,376	2,348	681	40,800	134
Chelan River	Chelan	4525	0	924	03-65	2,003	3,307	1,279	16,000	0
Wenatchee River	Peshastin	4590	1,028.04	1,000	28-65	3,010	5,386	1,729	32,300	183
Crab Creek	Irby	4650	1,386.30	1,042	42-65	96	295	31	8,370	2
Columbia River	Priest Rapids Dam	4728	0	96,000	17-65	114,100	159,000	86,600	692,600	4,120

1/ Regulated values for base period (1929-1958) 1970 conditions.
2/ Observed values for period of record.
3/ Denotes other short periods of record.
4/ Discontinued.

Average Discharge for Subregion 2 Figure 123, a plot of table 70, presents data on monthly discharge produced entirely within Subregion 2. These data are determined by subtracting the sum of the Canadian inflow of the Similkameen, Okanogan, Kettle, and Columbia Rivers and of the Spokane River inflow from Subregion 1 from the total discharge from the subregion represented by the station Columbia River below Priest Rapids Dam. The total inflow



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES

UPPER COLUMBIA SUBREGION 2

1968

FIGURE 122

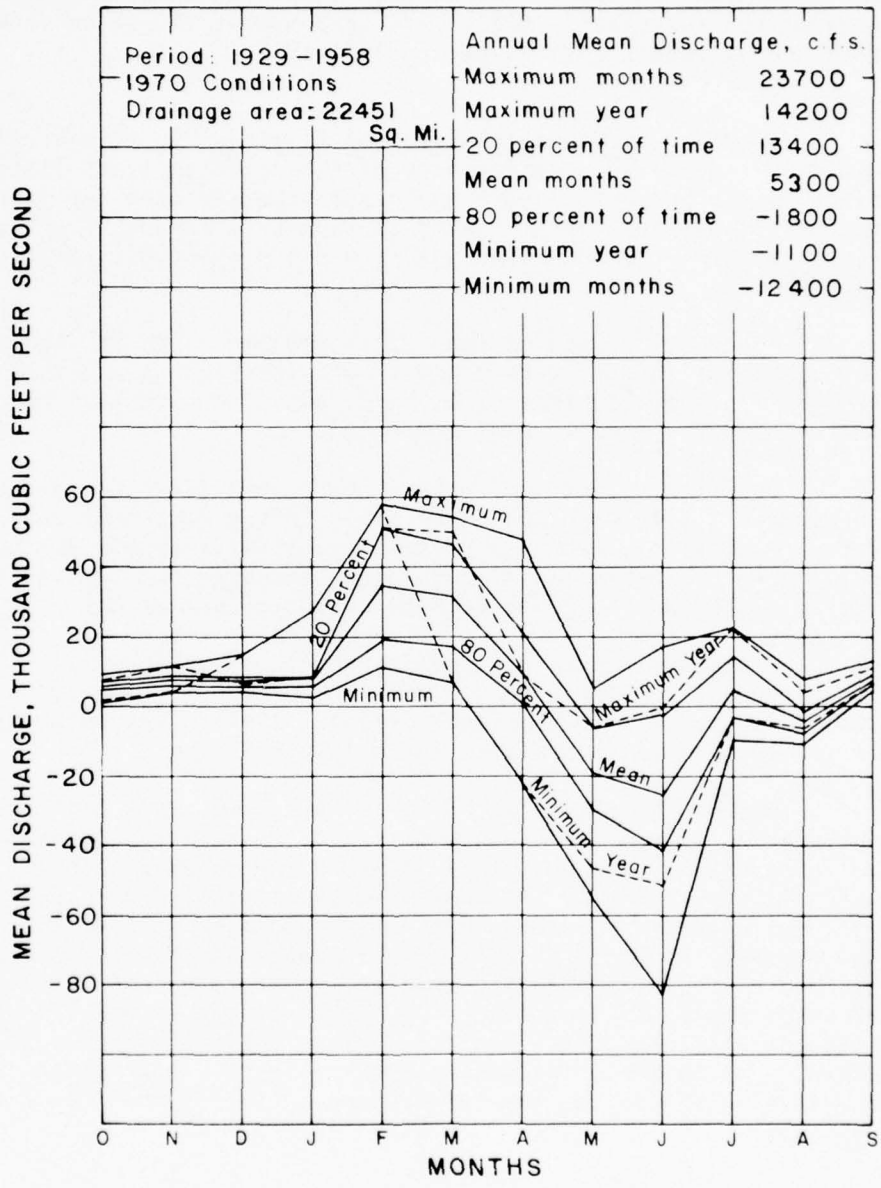


Figure 123. Monthly discharge, Upper Columbia Subregion

to the subregion averages approximately 96 percent of the total discharge from the subregion. Table 70 presents discharge from the subregion, inflow to the subregion and within-area generated flow of the subregion. Figure 122 is a map of isopleths showing mean annual runoff for the period 1931-1960.

Average Discharge for Selected Stations In this section of the report detailed data for each of the selected sites listed in table 69 are presented. The monthly discharges used for each of the selected sites are presented in tables 71 through 82. Hydrographs for several conditions of flow are presented in figures 124 through 135.

Frequency curves of mean discharge are shown on figures 136 through 147. These curves present both the highest and the lowest average flows for periods of 1, 3, 6, and 12 consecutive months. The mean annual flow is also indicated.

Duration curves for monthly and annual flows are presented in figures 148 through 159. The daily curves are shown only when data are available from Geological Survey daily summaries and are for the entire period of record. The discharge for the maximum day is listed on the graph because of space limitations.

Frequency curves of annual peak flows are shown in figures 160 through 171. These curves were computed using the standard method of the Corps of Engineers (Beard, 1962). The entire period of record is used in defining these curves.

Dependable yield of the river basins is given in tables 83 through 94. These tables show the lowest mean flows for from 1 to 10 consecutive years out of the 30-year base period. The relationship of these means to the 30-year mean is also given. The minimum year for all streams ranges between 78 and 9 percent of the mean and averages about 50 percent of the mean. These tables show that the use of the mean annual discharge to determine the total amount of water available in a stream is not realistic, even with carryover storage. The use of the minimum year or some point on the duration curve, such as the 90 percent point, presents a more practical approach to estimating the total amount of water that could be made available.

Variations in Discharge Long-term variations in discharge and precipitation are presented in figures 172 and 173. The means for the base period and for the entire period of record are shown. The mean precipitation of 39.53 inches at Lake Wenatchee and 33.01 inches at Stehekin for the 30-year base period are about 102 and 99 percent of the long-term (46 and 47 years in 1960) mean. This

indicates that the selected base period is representative of the long-term period. Also, the graphs show that the maximum and minimum of record occurred during the base period which again gives more meaning to the base-period record. The base-period discharge is about 98 and 97 percent of the long-term mean indicating that the data used in the analyses represent average conditions. The ratios of base-period discharge to long-term mean at other sites are similar. The graphs also present 5-year moving averages for precipitation and discharge. These averages show the relationship between precipitation and discharge. The data presented indicate no long-term trend, either declining or increasing, or long-term rhythmic cycle of precipitation or discharge.

The duration curves for selected sites are shown in figures 148 to 159 and show the range in annual flows. The range in annual flows during the 30-year base period varies considerably between some stations. The annual flow of maximum year varies between about 2 and 20 times the flow of minimum year.

Seasonal variations in runoff are clearly shown in the hydrographs of figures 124 to 135. Six of the 12 hydrographs show the spring runoff pattern exclusive of any winter flood pattern. Five show regulation, four of which are regulated for power. The remaining hydrograph indicates an exclusive rainfall pattern, primarily during the winter months. The Columbia River has the smallest variation in monthly flows due to the size of its drainage area and regulation.

River Profiles River profiles for selected streams are shown in figures 174 to 176. The profiles are based on Columbia Basin Interagency Committee River Mile Indexes.

Stream gradients are generally very steep. The Wenatchee River flows from an elevation of about 1,870 feet to an elevation of about 620 feet within 60 miles. One of the tributary creeks of Chelan River drops from elevation 4,450 feet to Lake Chelan, elevation 1,100 feet, within 5 miles. The Columbia River flows through the subregion for about 400 miles and from an elevation of about 1,300 feet to about 340 feet. With such gradient and large consistent flows, there is considerable hydroelectric power generation on the Columbia River.

(Narrative continued on page 255)

Table 70 - Modified Mean Discharge, in CFS, in Upper Columbia Subregion

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
MAXIMUM													
Total	98700	94500	102000	95000	109200	186200	137400	202600	181600	193300	163600	114400	
Canada	89800	83300	87600	68100	51400	132600	90200	197500	164600	170900	156200	101800	
Subregion	8900	11200	14400	26900	57800	53600	47200	5100	17000	22400	7400	12600	23700
MAXIMUM YEAR													
Total	95700	94500	97000	108100	206500	200600	173500	245800	212600	193300	111900	91000	
Canada	89100	83300	91100	100000	155200	151100	165100	251900	212700	170900	108200	80900	
Subregion	6600	11200	5900	8100	51300	49500	8400	-6100	-100	22400	3700	10100	14200
20%													
Total	86800	103400	86800	108100	153600	166700	117600	245800	112400	226400	99000	88900	
Canada	80400	95100	78900	100000	102500	121200	96500	251900	114900	214400	100400	80600	
Subregion	6400	8300	7900	8100	51100	45500	21100	-6100	-2500	14000	-1400	8300	13400
MEAN													
Total	88000	84900	101700	113500	133000	109800	120200	150900	149800	131200	102300	91800	114800
Canada	82800	78200	94800	105800	98500	78800	111200	170000	175700	127100	106500	84800	109500
Subregion	5200	6700	6900	7700	34500	31100	9000	-19100	-25900	4100	-4200	7000	5300
80%													
Total	82000	83100	91700	99300	110600	87900	134600	89700	69100	120900	92200	85800	
Canada	77600	78000	86900	94200	91400	71400	134000	119500	110700	124100	100000	80100	
Subregion	4400	5100	4800	5100	19200	16500	600	-29800	-41600	-3200	-7800	5700	-1800
MINIMUM YEAR													
Total	87400	88700	102000	95000	109200	77800	90700	157500	156700	102200	99400	85800	
Canada	85300	85100	87600	68100	51400	71800	112900	204000	208300	105400	105900	80100	
Subregion	2100	3600	14400	26900	57800	6000	-22000	-46500	-51600	-3200	-6500	5700	-1100
MINIMUM													
Total	85800	83900	102700	93500	79800	77800	90700	100000	196600	84000	91500	89200	
Canada	84100	80600	99000	91400	69200	71800	112900	154800	279400	93700	102600	85200	
Subregion	1700	3300	3700	2100	10600	6000	-22200	-54800	-82800	-9700	-11100	4000	-12400

Note: 1. Data available - Water Year 1930 through Fiscal Year 1958.
2. The first line under heading represents total flow leaving the subregion, the second line represents total flow entering the subregion, and the third line represents the discharge originating within the subregion.
3. Twenty percent and 80 percent represent the runoff available 20 percent and 80 percent of the time.

Table 71. Modified Mean Discharges, in CFS, Columbia River at International Boundary

Water Mean	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										203900	111500	81000	
1929	73300	68200	91800	93300	91200	55000	45600	74600	80400	88400	106700	86700	79600
1930	79700	82200	95300	88000	53300	47500	64000	91200	108900	95400	104300	81700	82600
1931	77500	81100	92300	72800	53800	49700	52200	76600	138100	100900	104000	76800	81300
1932	82400	81700	84000	61800	44200	54500	78700	151000	176300	71800	105600	79900	89300
1933	81500	53800	86600	115000	111700	46200	93900	153800	231800	144200	117400	86300	110200
1934	86400	62700	91400	93100	161900	153200	195800	197600	141200	104200	104700	90600	125400
1935	73200	57800	93800	115300	102200	83200	74500	110500	150500	119500	97300	86000	97000
1936	81000	77000	99400	108900	64300	58400	67000	136600	98200	83300	100300	80300	87900
1937	80300	79600	97100	88600	70500	40800	48600	62200	75700	79400	104100	81700	75700
1938	80500	71800	73000	93800	83900	42100	74400	115600	143500	143100	91200	81600	91200
1939	73000	67800	82500	116300	72100	63700	56100	119900	98600	90200	99900	81500	85100
1940	81000	73400	78500	122700	79000	59000	56400	91100	107600	97700	102000	83900	86000
1941	75900	66700	79800	86300	71300	61200	72400	61300	108000	87100	99400	74600	78700
1942	81600	66600	64700	95400	93200	61800	63600	108800	121500	97300	102700	77500	86200
1943	78300	51700	71300	91000	93300	63300	116800	160200	144200	117200	93600	76900	96500
1944	71800	67500	85500	89400	86200	56200	47000	73100	93800	77300	97700	75400	76700
1945	80200	79700	86000	62100	46100	42900	46300	69100	106800	80500	102500	77100	73300
1946	76600	72000	77900	78400	68400	41300	74600	146500	163600	118900	93900	78500	90900
1947	68500	67700	74700	100400	99700	97200	124800	162500	161300	130400	90900	74400	104400
1948	84300	77100	96800	95900	141600	113400	109300	160700	201200	165400	114600	83800	120300
1949	74200	69300	85300	114200	80600	40500	80400	129700	141400	75500	96400	77500	88700
1950	69400	55000	90700	111000	92000	77400	100800	146500	211900	172900	110000	85100	110200
1951	80600	71600	80800	89500	147200	119700	141500	163100	161800	156700	103000	77500	116100
1952	81000	82000	96000	110600	95400	57500	99300	149900	134700	133700	91700	77400	100800
1953	79000	77200	95400	78200	78500	50300	72900	131400	164000	116200	95700	76200	92900
1954	74400	78300	95400	108100	90200	77700	95500	181100	210400	194700	149000	94700	120700
1955	83300	86300	109100	120000	104400	64400	85500	70000	175800	153200	102600	76300	102600
1956	82700	72600	73700	86700	147800	137700	127400	185400	173900	173900	101600	78600	120200
1957	75200	70100	92300	120600	85500	44600	82900	155900	171600	117300	95800	78800	99200
1958	69400	66100	72400	106800	74100	62300	88000	143200	165000				
Mean	77900	71800	86400	97100	89400	67400	84500	126000	145400	119700	103000	80600	95800

Table 72. Observed Mean Discharges, in CFS, Kettle River near Laurier, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1929												174	
1930	184	202	154	77	98	212	3500	4250	4450	1340	348	194	1250
1931	210	225	208	194	222	575	2680	8890	5310	2110	437	398	1800
1932	340	400	339	230	338	705	6940	14200	9590	1850	540	388	2990
1933	390	692	916	636	519	670	4790	13500	14000	4440	766	458	3490
1934	800	1562	1101	890	975	2041	12170	9898	3783	759	307	231	2875
1935	322	1551	971	807	1407	1163	3766	11570	9683	4355	1089	462	3101
1936	381	402	311	274	215	330	6672	10820	6286	1636	455	313	2342
1937	265	206	173	131	131	260	1478	8608	8862	2073	552	293	1925
1938	334	567	540	609	513	1270	7017	13940	7768	1588	431	311	2916
1939	358	366	324	392	334	712	6118	10710	5959	2148	445	276	2352
1940	247	323	574	433	445	1616	7239	11640	5486	781	376	228	2451
1941	350	506	457	486	497	2822	7999	9304	6545	3161	998	3773	3078
1942	3815	2600	2652	1450	1164	983	6767	11900	10640	3836	1490	627	4005
1943	443	384	373	371	321	390	5226	7047	7995	2600	580	333	2173
1944	318	338	283	264	278	340	2728	8509	6794	1381	648	602	1874
1945	1096	1319	657	615	600	777	2921	15710	11170	1841	468	334	3137
1946	310	450	440	435	426	862	7100	17390	9004	2541	564	390	3340
1947	379	346	345	393	599	1031	4709	9477	4885	1536	665	426	2072
1948	1349	1650	956	681	497	550	3938	18000	14700	2767	2922	1270	4112
1949	1092	824	577	455	448	844	6687	13820	4363	1119	571	359	2609
1950	344	470	578	373	426	571	2392	10150	13460	2931	735	331	2734
1951	703	956	1253	1074	1098	1244	7776	16390	7801	2558	581	567	3511
1952	1624	1063	840	776	673	756	9732	16770	7946	2806	674	355	3672
1953	248	238	232	276	308	439	2144	11210	12200	4220	1080	794	2791
1954	834	999	690	573	673	752	2303	14350	10440	5765	1660	2203	3454
1955	1400	1918	1695	1035	869	661	2043	8600	14480	5273	1330	497	3321
1956	807	899	656	602	421	667	8486	17760	11210	2973	683	425	3802
1957	584	508	449	337	370	542	2631	18070	5553	1479	1002	424	2686
1958	430	482	399	395	898	2127	5577	16020	6672	1826	424	351	2980
Mean	688	774	660	526	544	894	5294	12362	8518	2567	800	601	2852

Table 73. Observed Mean Discharges, in CFS, Colville River at Kettle Falls, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							1080	850	348	209	108	89	
1929	115	148	138	93	74	239	249	214	132	52	29	38	127
1930	54	68	96	33	97	127	128	94	81	33	14	24	71
1931	43	65	68	85	90	151	205	112	50	28	12	23	77
1932	36	50	56	78	93	408	1410	900	450	100	45	35	304
1933	65	145	90	126	100	376	888	956	336	113	53	78	278
1934	103	139	346	557	663	653	815	364	148	63	41	59	327
1935	102	166	169	184	368	470	886	818	277	147	81	66	310
1936	90	111	126	155	92	245	398	343	165	57	30	53	156
1937	62	75	89	52	66	211	472	434	207	118	60	64	159
1938	80	164	192	435	335	1181	1776	1076	362	137	84	85	492
1939	130	142	123	190	116	319	522	225	147	59	26	38	170
1940	63	80	135	93	164	544	1058	462	144	43	40	62	240
1941	108	141	155	248	340	715	636	435	372	160	103	184	299
1942	181	233	463	355	459	421	797	757	862	351	152	115	428
1943	116	203	218	159	180	276	816	491	285	130	70	65	250
1944	103	148	116	111	155	262	337	225	178	61	41	42	148
1945	60	95	86	128	216	381	580	863	387	107	57	67	252
1946	77	132	161	198	188	497	1234	862	352	183	80	101	339
1947	120	160	188	150	261	312	518	315	193	73	45	75	200
1948	146	179	173	155	209	310	880	1744	1035	467	258	181	479
1949	194	239	206	138	251	821	1326	842	305	132	94	95	387
1950	132	167	139	120	193	632	1019	1032	482	205	116	91	361
1951	157	233	385	455	727	823	1801	1098	388	184	113	129	538
1952	192	201	266	259	405	642	1878	1083	398	232	133	128	483
1953	137	157	194	338	328	348	581	904	589	208	114	113	334
1954	126	149	184	163	319	420	653	648	385	175	95	128	286
1955	127	156	144	151	149	183	554	867	420	272	121	97	271
1956	137	140	205	341	269	725	2128	1137	380	199	136	132	493
1957	147	149	161	141	202	395	477	787	447	159	98	89	271
1958	137	152	178	223	608	895	1421	849	321	168	85	100	426
Mean	111	146	175	197	257	466	881	698	343	149	82	85	299

Table 74. Modified Mean Discharge, in CFS, Columbia River at Grand Coulee Dam, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										200300	99500	83600	
1929	75600	71800	95500	98200	104100	68900	84300	56600	48200	74600	92100	88900	79900
1930	82400	84500	98300	88100	86100	78000	65200	69500	74800	90200	92800	87100	83100
1931	82300	85600	96400	78200	86200	85100	70100	70200	95900	94800	93700	81700	85600
1932	83400	83700	97700	89200	104200	69100	84400	145400	139400	61100	92400	84200	94500
1933	85500	60900	94400	121000	160700	94700	117400	179400	158700	148600	112100	93000	118900
1934	92400	90900	117700	128500	192600	184200	214300	189600	145100	96100	95400	95300	136800
1935	77100	63500	101300	124100	120300	103600	112500	137900	127800	116300	88500	90700	105300
1936	84900	80900	103200	114600	75300	75600	81400	150200	107700	78800	91000	84400	94000
1937	83600	83300	101000	92200	95800	79500	60100	64800	49700	79900	98600	86600	81200
1938	84000	77700	81500	104600	118200	82900	107900	126100	126100	143900	85200	85400	102000
1939	77900	72100	86800	122100	86100	79500	105700	96300	103000	88900	93600	85900	91500
1940	82000	78300	83900	127700	95000	84000	106100	79100	92400	90600	91700	87900	91600
1941	78900	71900	87000	94100	86800	81500	124300	70100	62400	78900	88200	83600	84000
1942	87300	75100	83300	105500	110800	79200	108200	92200	134000	95200	95000	81700	95600
1943	81500	58400	78300	97000	143200	111600	123300	186200	100400	118400	85700	80700	105400
1944	75400	70900	90000	94500	104000	72700	83100	77000	51700	69400	88100	79100	79600
1945	83900	84400	97600	80500	86300	81200	72100	103200	40000	78400	92700	81300	81800
1946	79800	77900	86900	87400	112000	86500	108900	154900	143100	115100	89600	83400	101800
1947	72400	75600	87500	109600	132000	129800	146500	156800	139000	123700	83000	79300	111300
1948	91200	86400	106100	107300	196100	163000	137000	180200	190500	164400	108300	88600	134900
1949	77800	74400	90600	120100	105300	73900	114900	127400	139700	65100	83000	80200	96000
1950	72500	59900	96100	117100	147100	138700	129000	176500	154800	179100	96000	86400	121100
1951	83800	77000	93100	102200	212500	174800	179000	156200	137800	158000	98000	82100	129500
1952	87900	89600	104500	119500	146500	107400	123100	162300	117400	132100	80300	80000	112600
1953	80800	78900	99200	87400	115400	82400	92900	157300	144200	120800	89200	81900	102500
1954	77500	81900	101500	114200	145900	129600	116500	180900	193900	199300	148600	103000	132700
1955	88800	92300	115900	125800	137000	95400	101600	91100	148200	152900	97000	79600	110500
1956	88000	80400	88400	98400	198500	193200	162400	200400	160400	170800	93500	81500	134600
1957	79100	74500	98600	126800	136800	94100	106200	150400	145200	107600	85800	82000	107200
1958	72900	70900	78500	116600	117700	99800	115100	148000	149500				
Mean	81700	77100	94700	106400	125300	102700	111800	131200	120700	116400	94100	85000	103900

Table 75. Observed Mean Discharges, in CFS, Okanagan River at Okanagan Falls, British Columbia

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							1120	1940	2580	2320	1610	1060	
1929	971	851	259	46	33	29	35	473	347	134	136	72	284
1930	34	25	9	8	8	10	57	289	209	110	99	61	77
1931	57	48	10	7	6	27	50	86	66	93	88	61	50
1932	48	68	10	38	357	639	677	883	846	624	479	458	427
1933	410	376	640	625	267	386	751	1080	1180	954	747	560	668
1934	562	661	706	719	744	724	946	933	818	725	421	343	691
1935	434	504	481	568	619	660	656	937	956	866	808	798	691
1936	807	792	567	374	251	246	377	790	876	819	647	541	592
1937	554	514	400	233	161	379	634	786	915	508	310	273	473
1938	279	385	599	666	634	598	642	1020	751	318	178	197	522
1939	192	176	221	145	126	189	428	512	464	390	372	289	293
1940	233	209	214	156	65	145	172	200	221	184	154	163	177
1941	167	179	216	230	246	448	415	209	310	252	322	424	285
1942	533	613	756	781	657	215	346	468	1070	1250	1070	962	727
1943	858	891	705	584	409	530	728	732	546	353	225	190	564
1944	164	161	148	138	142	127	121	216	735	424	176	147	225
1945	165	225	580	527	447	578	629	1000	1030	673	522	300	557
1946	466	586	795	611	538	768	806	1240	1180	1000	918	890	819
1947	902	744	710	500	272	137	178	325	286	203	324	335	411
1948	259	274	421	625	326	168	435	904	1370	1350	1400	1390	745
1949	1250	1420	1220	1040	904	844	856	1160	735	575	564	565	928
1950	522	406	389	369	476	835	785	982	1170	728	614	478	647
1951	498	545	646	686	721	836	893	1230	1240	1180	865	711	838
1952	765	787	791	687	800	560	815	1270	953	832	729	742	811
1953	598	235	173	170	182	192	201	534	483	684	680	601	396
1954	561	578	606	508	846	637	399	519	714	1080	1030	824	691
1955	645	772	773	690	680	664	644	624	938	883	834	846	750
1956	467	297	281	475	575	679	809	1130	1310	1310	692	500	711
1957	437	406	542	526	487	459	448	769	740	734	646	679	574
1958	621	533	522	516	515	506	873	664	584	548	551	506	578
Mean	482	475	480	442	416	441	527	734	768	719	589	516	549

Table 76. Observed Mean Discharges, in CFS, Similkameen River near Nighthawk, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1929	656	517	371	247	217	345	427	3960	5220	1190	376	269	1150
1930	330	306	285	215	442	466	3470	5230	5620	1740	533	391	1590
1931	416	484	353	352	473	496	911	6060	2760	945	328	411	1170
1932	395	532	387	344	774	1370	2290	7960	6090	1650	568	374	1900
1933	523	1470	1070	702	496	531	1480	6270	12200	5030	1260	631	2640
1934	1595	2599	1661	1302	1141	2206	13510	11070	5377	1516	645	441	3588
1935	489	1287	838	779	2235	1103	1315	8704	9598	3675	1243	617	2654
1936	498	490	462	405	265	409	2724	8003	5287	1158	385	323	1703
1937	311	310	313	218	282	408	594	5982	11220	2680	791	539	1971
1938	665	963	702	643	535	670	2536	11400	8385	2108	599	457	2481
1939	462	458	502	624	424	614	2513	6861	5115	2084	535	335	1717
1940	367	575	911	393	440	525	2060	5065	2795	665	295	219	1194
1941	489	440	418	375	345	575	2482	3424	3378	1317	587	1076	1243
1942	2180	1516	1441	765	661	544	2396	7937	8125	2489	892	468	2459
1943	406	474	605	432	590	544	2964	5904	9793	5128	1161	540	2381
1944	473	470	393	327	319	373	922	4786	6659	1815	690	479	1475
1945	577	578	501	545	635	473	633	7261	9423	1139	604	484	1990
1946	678	1152	666	554	491	539	1954	12250	8447	2987	834	529	2603
1947	529	521	479	442	518	756	2969	9277	5598	1612	684	480	1997
1948	762	837	682	514	466	446	1131	11130	17130	3668	2625	1608	3413
1949	1344	926	736	639	580	635	2809	14680	7528	2283	944	713	2834
1950	762	1737	1898	749	735	735	1013	7626	17980	5323	1418	618	3383
1951	811	1129	1637	1115	1393	988	3515	13980	9288	3561	951	851	3279
1952	862	814	542	456	537	540	2121	8616	5355	2265	752	446	1947
1953	330	338	320	448	609	493	1191	8531	9530	3932	1042	609	2288
1954	822	914	740	524	670	622	1014	9548	11650	8004	2195	1614	3207
1955	1185	1692	1370	778	599	533	744	4060	14090	6278	1490	618	2788
1956	1181	2212	1019	802	540	598	2903	13800	11140	3784	1058	665	3313
1957	1091	1071	1016	589	607	655	1228	14900	6654	1655	826	491	2584
1958	453	579	502	513	474	526	1059	8986	4795	1337	422	364	1677
Mean	721	913	761	560	616	657	2229	8442	8208	2817	907	596	2286

Table 77. Observed Mean Discharges, in CFS, Okanogan River near Tonasket, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1929								3890	5530	1330	406	270	
1930	416	413	399	360	581	529	3240	5090	5660	1840	515	365	1620
1931	442	588	443	439	600	525	770	5630	2730	908	231	335	1140
1932	403	663	491	398	883	2060	2920	8620	6840	2270	915	696	2260
1933	887	1870	1850	1500	1040	916	1980	7200	13300	5940	1810	1090	3280
1934	2113	3233	2437	2011	1861	2855	13220	12270	6214	2114	1055	626	4168
1935	950	2203	1755	1388	2889	1896	2011	9283	10710	4727	1881	1251	3409
1936	1312	1359	1199	944	613	701	2942	8845	6484	1930	885	706	2330
1937	842	895	828	504	532	704	1258	6485	11950	3382	958	731	2424
1938	1059	1496	1415	1394	1345	1658	3841	11860	9384	2388	711	574	3100
1939	736	784	821	927	611	849	2946	7356	5535	2321	696	516	2015
1940	658	929	1253	715	675	704	2236	5219	2964	605	319	231	1377
1941	710	712	739	700	687	957	3054	3790	3720	1553	662	1492	1565
1942	2756	2181	2307	1800	1515	1008	2897	8632	9640	3932	2064	1406	3352
1943	1352	1576	1598	1115	1317	1101	3766	6467	10170	5423	1270	575	2980
1944	655	731	594	492	656	539	944	4747	7925	2005	601	515	1697
1945	764	893	1026	1193	1262	1121	1339	8148	11250	2796	1030	707	2629
1946	1117	1807	1551	1414	1176	1408	2964	13320	9787	3942	1615	1335	3466
1947	1455	1445	1326	1144	951	1023	2941	9161	5761	1742	824	757	2386
1948	1194	1223	1188	1259	1051	748	1620	10980	20450	5025	3928	3039	4302
1949	2788	2556	2171	1865	1805	1768	3689	15530	8336	2659	1349	1197	3824
1950	1336	2200	2526	1166	1568	2382	2575	8762	19360	6152	1966	964	4246
1951	1384	1812	2342	1984	2380	2027	4583	15710	11600	4596	1708	1659	4324
1952	1746	1765	1359	1246	1527	1329	3093	10560	6459	3074	1293	1085	2882
1953	1072	778	674	757	950	770	1384	9323	10510	4607	1557	1211	2807
1954	1441	1635	1459	1141	1570	1307	1343	9937	12940	9510	3031	2513	3998
1955	2093	2618	2419	1745	1469	1265	1508	4627	15160	7179	2317	1402	3655
1956	1782	2653	1365	1450	1120	1541	3553	14460	13020	4953	1693	1097	4062
1957	1657	1629	1691	1164	1262	1322	1694	16010	7601	2325	1265	1138	3249
1958	1325	1206	1205	1169	1188	1194	2060	9863	5522	1689	728	814	2339
Mean	1257	1512	1394	1151	1210	1249	2840	9059	9217	3491	1329	1017	2894

Table 78. Observed Mean Discharges, in CFS, Methow River at Twisp, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							1030	6110	2810	1270	316	214	
1929	268	274	253	199	183	205	180	2020	2790	588	185	148	609
1930	209	233	208	183	238	280	2270	3100	3440	1060	314	228	980
1931	245	301	234	229	249	279	772	3540	2080	588	223	236	752
1932	236	319	247	226	356	990	1550	4540	3670	1010	329	222	1140
1933	289	676	507	345	257	313	1090	3650	6590	3020	633	321	1480
1934	732	1183	876	552	611	1773	7692	5974	3544	968	323	212	2036
1935	258	708	613	578	958	730	1278	5312	6257	2188	561	302	1645
1936	262	304	251	230	209	204	1372	3481	3368	532	195	196	883
1937	189	244	223	178	185	212	310	3110	6851	1674	338	270	1148
1938	392	574	415	361	322	498	2052	6655	5772	1379	297	230	1583
1939	283	311	280	275	248	311	1405	2955	1981	853	221	198	779
1940	204	234	261	209	230	331	1353	4506	2540	468	205	176	895
1941	330	406	314	281	270	619	2765	3180	2777	726	318	669	1054
1942	845	666	577	335	356	355	1883	5876	4648	1528	422	210	1480
1943	233	300	261	228	275	311	2265	3405	5496	3051	594	220	1388
1944	280	312	267	243	231	248	631	2979	3321	765	257	164	808
1945	258	292	264	261	254	269	495	4035	5198	1199	271	194	1084
1946	282	453	308	287	287	341	1645	7695	5003	1926	482	363	1597
1947	380	351	292	248	280	733	2229	5190	3300	965	340	236	1216
1948	439	523	438	310	298	282	876	6052	7985	1971	1185	565	1743
1949	634	434	343	269	240	344	2208	7491	3683	1288	430	299	1480
1950	355	636	748	399	358	357	947	4761	11030	3943	865	257	2036
1951	525	612	553	491	762	616	3632	9385	6538	2426	668	493	2231
1952	566	504	356	324	297	363	1991	5770	3434	1441	464	255	1317
1953	301	285	247	257	261	378	1052	5621	6503	3181	673	276	1592
1954	456	456	371	302	318	349	855	5880	6063	4392	1205	694	1788
1955	572	702	627	416	336	316	637	2501	7721	2937	721	323	1484
1956	548	989	526	377	274	321	2910	9256	7006	2461	697	394	2149
1957	536	521	459	322	338	363	1124	9515	3825	942	362	195	1553
1958	342	349	292	268	299	404	1144	8202	3793	981	282	235	1392
Mean	382	472	387	306	326	436	1687	5188	4874	1691	470	292	1376

Table 79. Observed Mean Discharges, in CFS, Chelan River at Chelan, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							657	3550	2860	2850	1420	1680	
1929	1250	1520	1790	2340	2310	654	356	168	235	1600	2090	2410	1390
1930	2370	2310	1840	1430	138	43	72	154	890	2210	2200	1760	1300
1931	1550	1650	2040	1400	427	209	171	770	3280	2020	2270	2280	1510
1932	2150	1360	1200	336	473	665	880	3970	4950	2570	1500	1390	1790
1933	1790	764	2270	1160	1820	1850	588	1240	6520	5290	2300	1350	2250
1934	2457	3287	2804	2577	2958	1048	4416	6731	4462	2765	2196	2005	3139
1935	2007	787	844	1516	3949	2047	872	2490	5796	3593	2155	2237	2344
1936	2183	1997	2119	1581	1461	367	386	538	3867	1919	2156	2183	1727
1937	2150	2106	1810	1338	1178	676	899	544	1268	3387	2197	2166	1647
1938	2125	2050	1475	1155	906	868	746	3137	6293	3193	2140	2126	2188
1939	2165	2164	2130	899	694	931	765	863	1193	2670	2133	2105	1566
1940	2198	2221	2189	1788	980	1073	916	597	2319	2308	2200	2086	1742
1941	2143	2111	1299	1204	962	931	350	118	2176	1791	1841	1552	1374
1942	718	829	1158	1418	1302	1050	980	2491	3249	2677	1374	1540	1567
1943	1884	1426	902	1395	1302	1676	979	960	4691	5117	2188	1995	2046
1944	2059	2116	1891	1478	210	174	23	60	1068	1475	1467	1941	1167
1945	1984	2022	1957	1144	146	199	820	893	3051	2504	1741	2065	1550
1946	2124	1652	1294	1399	1829	1442	1549	1934	4238	3786	2222	2183	2137
1947	2024	1898	1465	1783	1535	1667	1182	1961	3018	2468	2220	2065	1943
1948	969	914	1236	2087	1749	1430	1140	2308	9566	2802	2251	2027	2341
1949	1842	1890	2365	2320	1798	1191	1200	1766	3635	3102	2202	2157	2124
1950	2160	1649	1371	2125	1512	1379	965	4040	6713	6451	2477	1355	2693
1951	952	1253	1725	1679	4308	2260	2657	6295	5576	4305	1651	1729	2855
1952	651	1988	1855	3651	1733	1446	1472	1400	1499	2257	1628	2063	1805
1953	1737	2067	1675	1651	1722	2016	1700	1496	797	4078	1967	1965	1910
1954	1623	2070	2206	2197	1933	2072	1089	2333	3284	6340	2980	2137	2531
1955	2188	2213	2232	2227	2192	2155	1563	97	2502	4590	2366	2098	2203
1956	1647	1247	1886	1761	3047	2325	1624	5660	7133	5386	2126	2033	2989
1957	2224	2283	2307	2302	2239	2093	1179	1302	5053	2292	1160	2236	2217
1958	2286	2317	2303	2222	1504	1910	1273	772	4063	2178	977	2130	1994
Mean	1854	1805	1788	1719	1611	1262	1094	1903	3746	3260	2027	1964	2003

Table 80. Observed Mean Discharges, in CFS, Wenatchee River at Peshastin, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1929	1170	710	570	450	450	806	1480	6360	6680	2670	862	442	1890
1930	376	329	474	421	953	1680	4930	5030	4510	2420	783	458	1860
1931	577	697	482	700	1220	1540	2760	8230	5590	1730	572	506	2050
1932	509	1220	627	895	2160	3530	4410	8130	8980	4050	1300	602	3030
1933	867	4460	2710	1680	961	971	2900	5920	11700	8580	2820	1250	3740
1934	3640	4546	5648	3697	3042	5172	11250	8911	6079	2644	1119	683	4706
1935	1086	3897	1888	3505	3131	2095	2780	8208	9941	4945	1447	854	3644
1936	612	525	497	550	486	1018	4693	11090	8934	2257	790	588	2671
1937	475	339	728	493	476	839	1923	6602	11440	4481	1071	637	2463
1938	720	1778	1697	1445	872	1294	4696	9777	10070	3345	816	522	3091
1939	622	845	1310	1841	901	1372	4234	7447	5516	3481	981	495	2429
1940	611	1151	2037	883	923	1856	4385	7773	5214	1586	660	543	2304
1941	1045	778	1072	643	618	1867	4334	4414	3191	1164	587	953	1725
1942	2089	1761	2308	887	705	880	3661	5770	5499	2801	789	426	2305
1943	336	782	1122	1190	972	1239	5501	6854	10070	7572	1835	688	3186
1944	627	647	1444	616	651	1126	2518	5677	5062	1576	577	766	1775
1945	780	846	1293	2125	1855	1090	1712	7404	6809	2667	785	682	2339
1946	1044	1452	820	849	657	1113	3418	12110	9592	4993	1394	683	3191
1947	930	849	1863	1457	1822	2884	5250	10140	7097	3265	1125	733	3125
1948	2306	2288	1576	1050	979	972	2441	9433	14750	4234	1639	933	3547
1949	1507	1161	1175	689	989	1450	4572	12410	9379	4560	1533	1046	3385
1950	1455	4001	2965	1495	1121	1843	2539	7448	14650	9491	2687	1017	4237
1951	2255	2893	3563	2194	3944	1862	5379	11250	9754	4651	1357	802	4154
1952	1848	1765	1081	809	830	948	3979	8314	6723	3367	1081	615	2616
1953	463	384	421	2076	2917	1588	2883	7955	8183	6888	1967	802	3045
1954	979	1558	2043	1371	1143	1325	2729	9400	10230	10350	4003	1746	3928
1955	1329	2889	1732	1019	1140	880	1706	5305	13320	7695	2420	942	3369
1956	2034	4511	2107	1213	906	1001	5719	13800	13030	8358	2149	1105	4666
1957	1901	1853	3794	1199	932	1474	3348	12430	7723	2577	1069	699	3267
1958	655	903	992	873	1330	1594	3009	12390	7734	2019	808	653	2755
Mean	1162	1727	1668	1277	1301	1577	3838	8533	8482	4428	1387	752	3010

Table 81. Observed Mean Discharges, in CFS, Crab Creek at Irby, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1942												12	
1943	9	9	9	12	70	122	202	97	58	40	29	20	56
1944	16	15	18	30	160	138	61	27	24	19	15	10	44
1945	8	6	6	12	181	62	59	24	20	19	12	10	34
1946	7	6	35	106	290	228	112	59	45	29	19	14	[illegible]
1947	13	11	13	29	103	68	32	24	16	12	8	7	28
1948	6	5	5	14	241	132	61	164	451	109	61	42	106
1949	35	29	36	35	814	447	156	78	42	30	21	15	140
1950	14	16	14	13	529	967	193	88	70	42	30	23	165
1951	19	17	22	49	424	497	195	92	56	32	23	20	119
1952	20	22	25	35	279	260	195	82	46	31	22	16	85
1953	17	17	22	53	92	89	60	35	28	19	13	10	38
1954	10	12	14	20	128	140	64	29	26	18	11	10	40
1955	11	13	20	72	303	166	79	42	22	18	14	10	63
1956	8	8	295	1163	510	1141	248	83	47	29	22	14	299
1957	15	21	29	28	691	288	95	47	56	27	23	13	107
1958	10	11	14	129	151	186	101	45	29	22	14	10	60
Mean	13	14	36	112	310	308	155	63	65	31	22	15	95

Table 82. Modified Mean Discharges, in CFS, Columbia River below Priest Rapids Dam, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										224000	109900	90900	
1929	82300	78400	101100	103000	108000	72600	85200	62000	71300	87600	97000	94300	86900
1930	87900	89800	102700	93500	90700	83100	72500	81700	90200	98800	97600	92700	90100
1931	86800	89600	100000	82200	90800	88400	74500	81700	104000	102200	99400	85800	90400
1932	87400	88700	102000	95000	109200	77800	90700	157500	156700	74600	97800	90600	102300
1933	89600	69700	102700	128800	167100	97900	118900	185900	196600	180300	121900	100200	130000
1934	100600	104200	128000	139600	203400	196700	243100	221200	168800	104500	100000	101000	150900
1935	82000	72400	109200	132100	132000	111300	117600	147500	156900	131100	99300	96900	115700
1936	90200	86200	107900	119400	79800	80400	81500	160500	123300	83400	93200	89400	99600
1937	87600	87500	105400	96600	100600	84400	63500	70400	76900	87800	102500	91500	87900
1938	89300	83100	88700	111000	124100	86800	110700	142400	146800	154100	90400	89200	109700
1939	83400	77100	91700	127200	90400	83000	108500	100000	112400	95500	96900	90800	96400
1940	85800	85400	90500	133200	98000	89200	110700	89700	101700	94100	96000	91600	97200
1941	84300	79600	92500	99400	92200	87900	137400	76900	73200	84000	91500	88700	90600
1942	96000	82700	91400	114100	119000	84600	115900	105300	148400	101400	102000	88300	104100
1943	87900	65800	86800	105600	150600	116000	132400	202600	134300	147700	101300	88900	118300
1944	81300	77200	96800	99300	110600	78700	88200	88000	69100	81200	94600	84400	87400
1945	90100	90900	103600	88500	94000	86500	77800	112800	67800	88800	99300	87400	90600
1946	86200	85700	92500	95600	117700	90800	112200	178100	170900	134500	94400	91100	112500
1947	79600	81300	93100	116000	137800	135200	155900	184400	163400	136300	89900	85500	121500
1948	94700	96000	113900	113200	202800	166700	137700	193400	257600	194700	122900	101900	149600
1949	88000	83600	97700	126000	114000	80000	123000	166400	181600	82700	92200	87800	110200
1950	79000	69500	106800	123300	155200	145400	136400	197500	200200	211900	114800	96200	136400
1951	91800	87900	102600	115400	223400	186200	195600	188800	171300	174300	110300	91700	144900
1952	94200	98800	112200	126500	155200	113300	134600	172400	135800	145100	88700	85900	121900
1953	85500	83900	103900	95500	124800	87800	98700	174000	168300	141400	99000	89200	112700
1954	83600	89800	110300	122100	153600	135200	124200	191200	224900	228400	163600	114400	145100
1955	98700	103400	126600	132400	143900	102700	110500	104300	181800	193300	111900	91000	125000
1956	95700	94500	97000	108100	206500	200600	173500	245800	212600	200400	103600	90700	152400
1957	84400	82900	109400	132100	145100	101200	113600	182700	176500	120900	89000	86900	119000
1958	77500	75200	83300	120200	123700	107300	125000	172800	172900				
Mean	87800	84700	101700	113200	132100	108600	119000	147900	147200	132800	102400	91800	114100

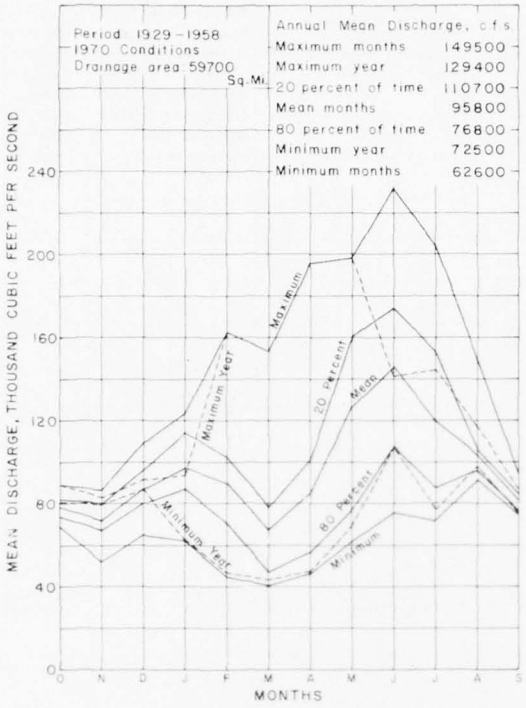


Figure 124 Monthly discharge, Columbia River at International Boundary

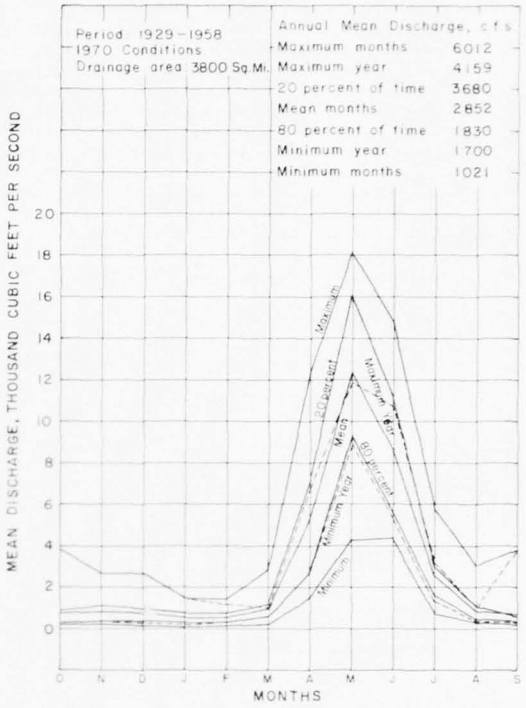


Figure 125 Monthly discharge, Kettle River near Laurier

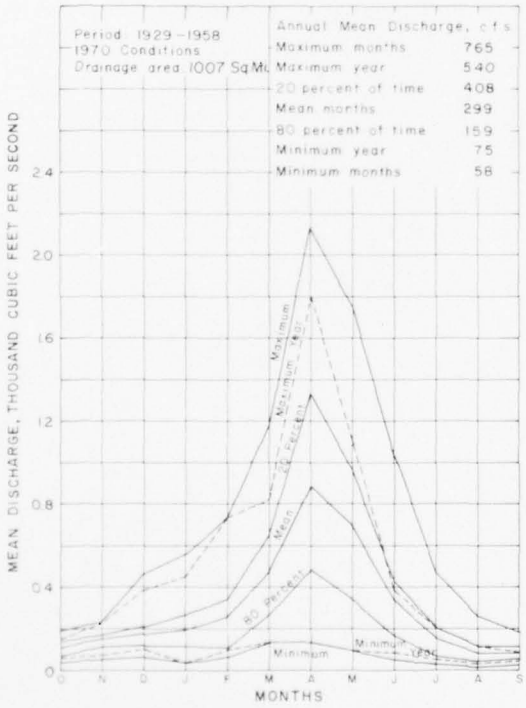


Figure 126 Monthly discharge, Colville River at Kettle Falls

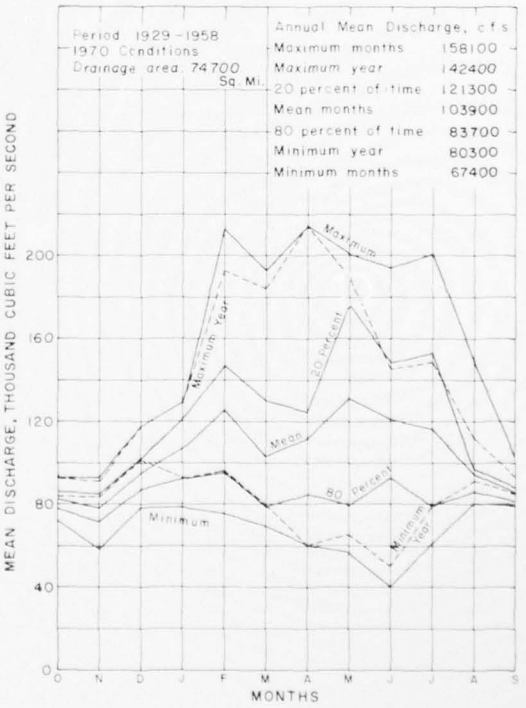


Figure 127 Monthly discharge, Columbia River at Grand Coulee Dam

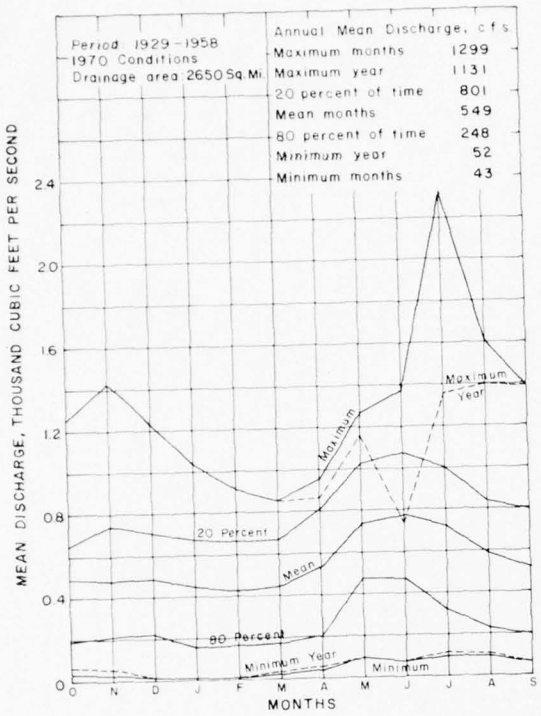


Figure 128 Monthly discharge, Okanagan River at Okanagan Falls, B. C.

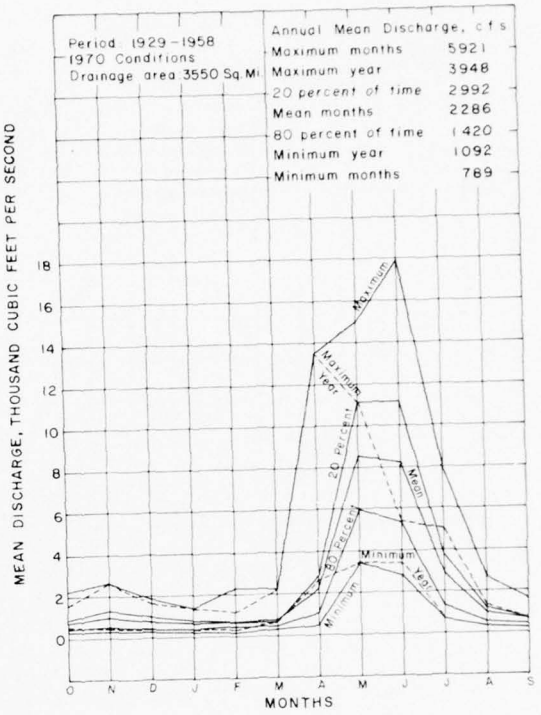


Figure 129 Monthly discharge, Similkameen River near Nighthawk

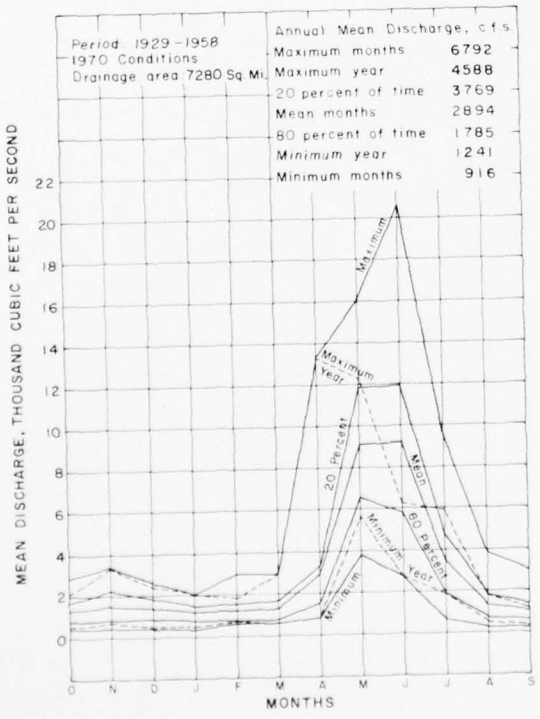


Figure 130 Monthly discharge, Okanogan River near Tonasket

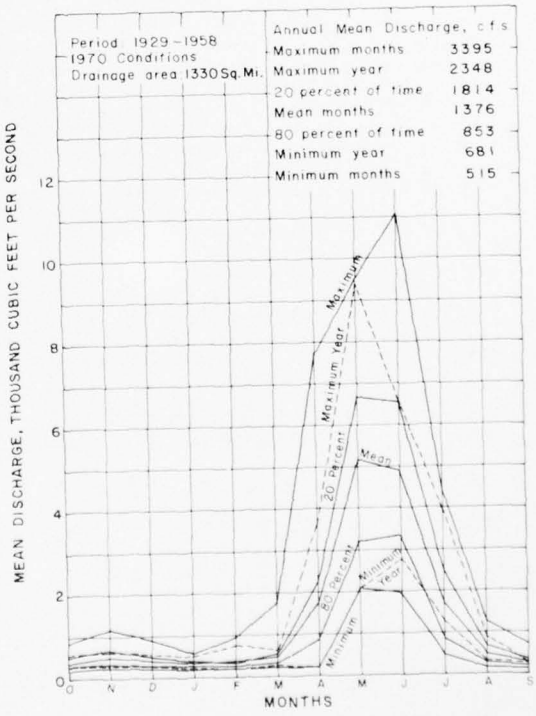


Figure 131 Monthly discharge, Methow River at Twisp

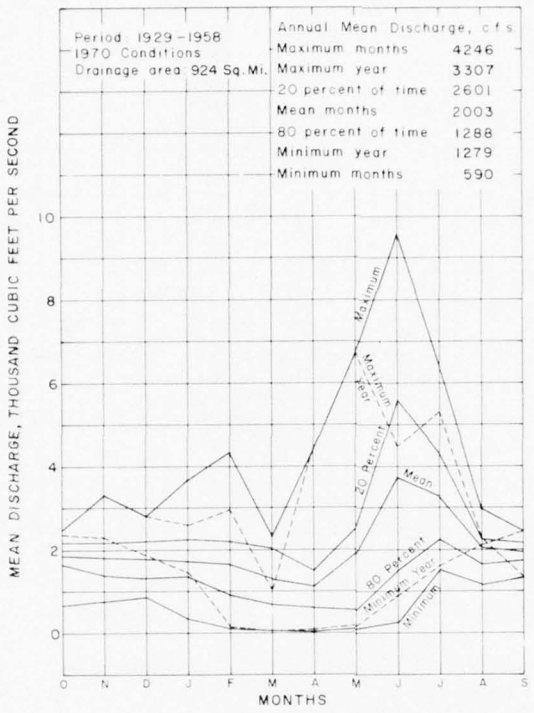


Figure 132 Monthly discharge, Chelan River at Chelan

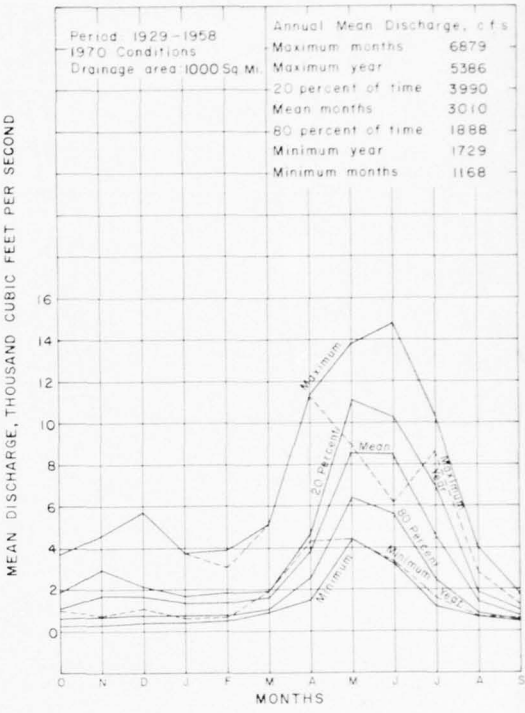


Figure 133 Monthly discharge, Wenatchee River at Peshastin

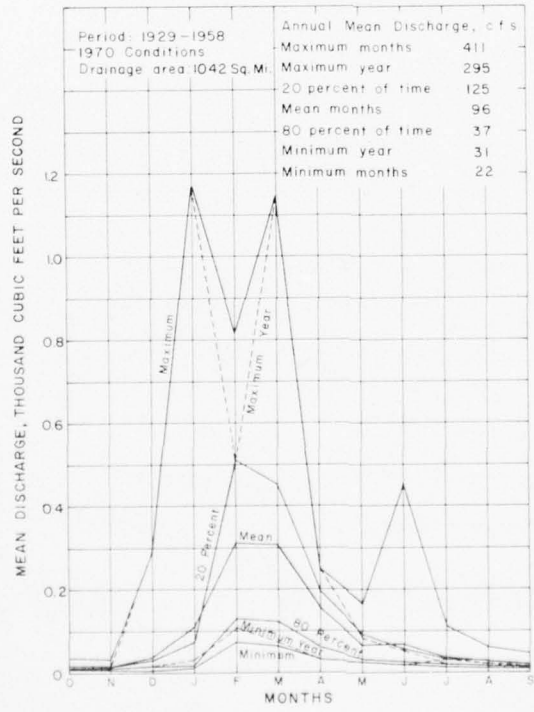


Figure 134 Monthly discharge, Crab Creek at Irby

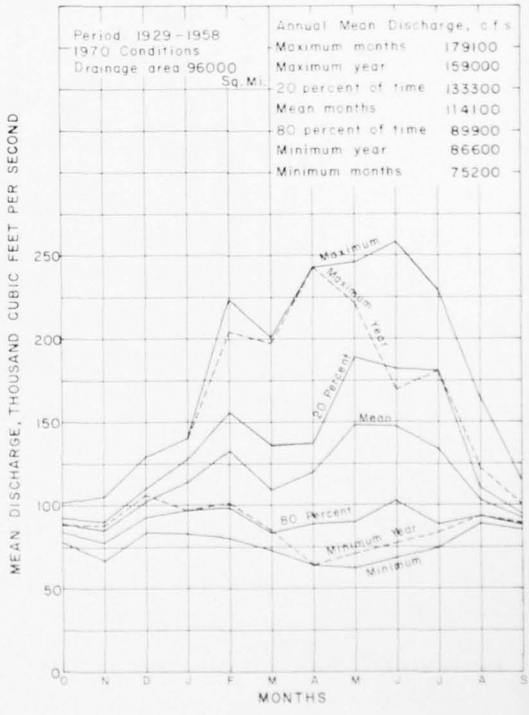


Figure 135 Monthly discharge, Columbia River below Priest Rapids Dam

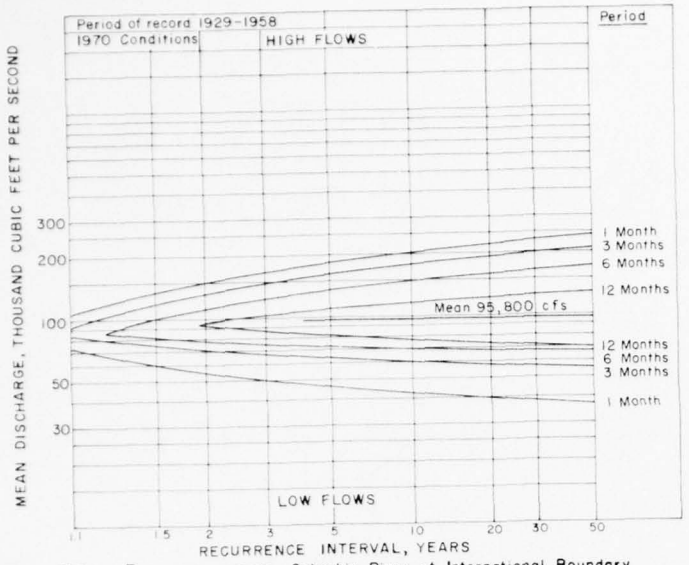


Figure 136 Frequency curves, Columbia River at International Boundary

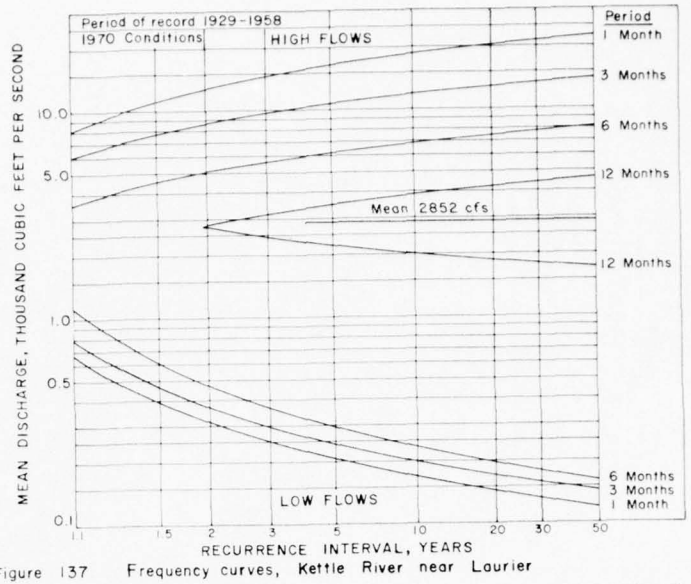


Figure 137 Frequency curves, Kettle River near Laurier

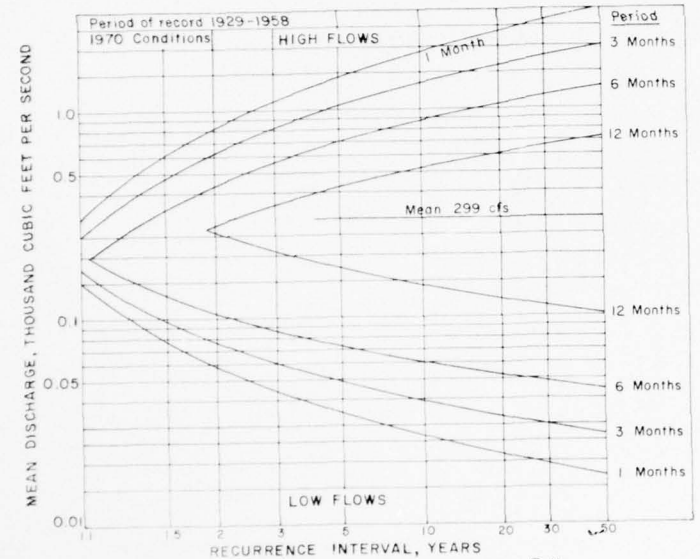


Figure 138 Frequency curves, Colville River at Kettle Falls

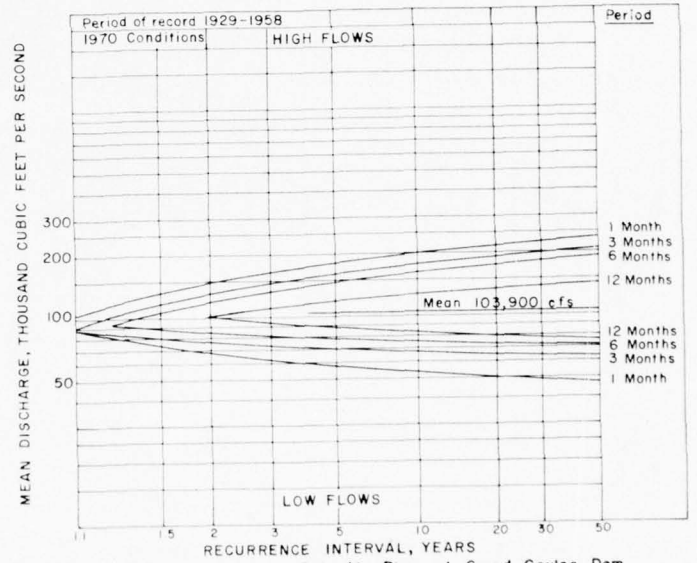


Figure 139 Frequency curves, Columbia River at Grand Coulee Dam

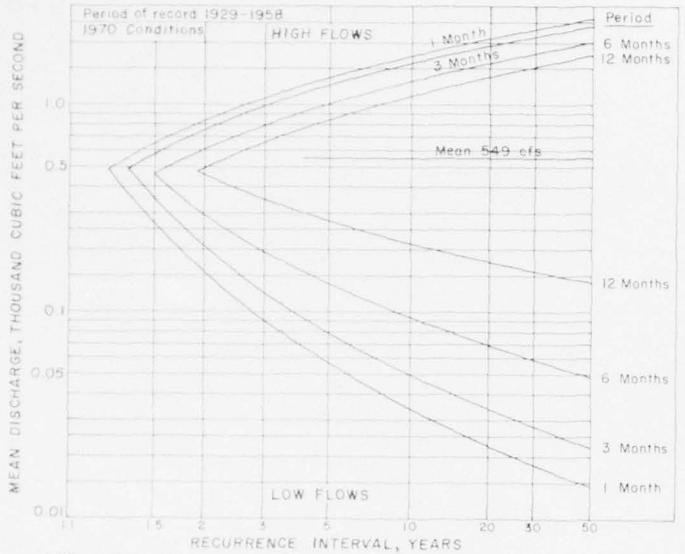


Figure 140 Frequency curves, Okanagan River at Okanagan Falls, B.C.

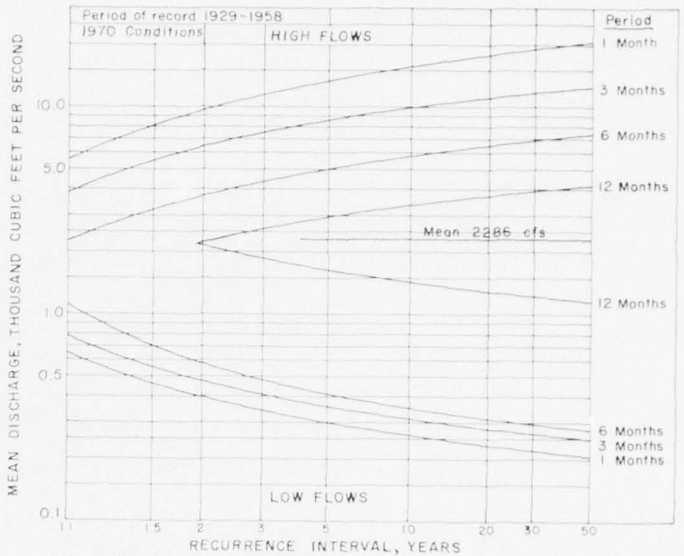


Figure 141 Frequency curves, Similkameen River near Nighthawk

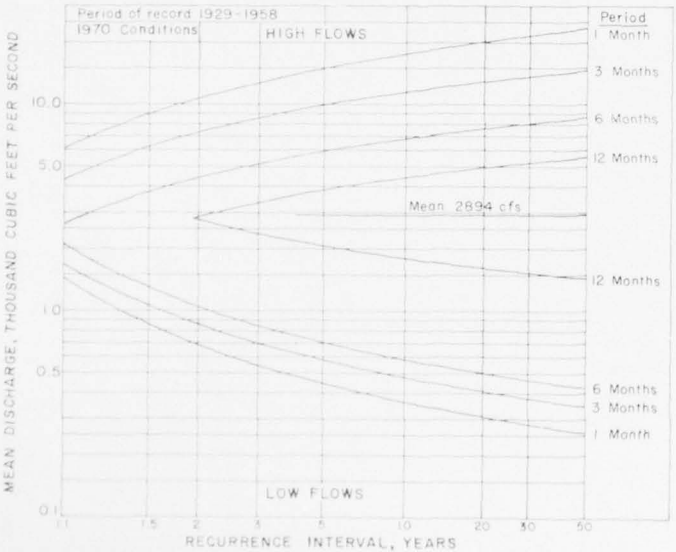


Figure 142 Frequency curves, Okanogan River near Tonasket

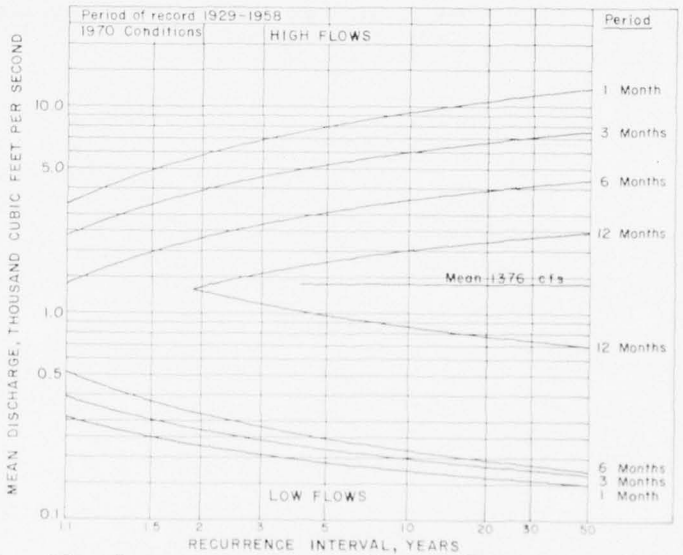


Figure 143 Frequency curves, Methow River at Twisp

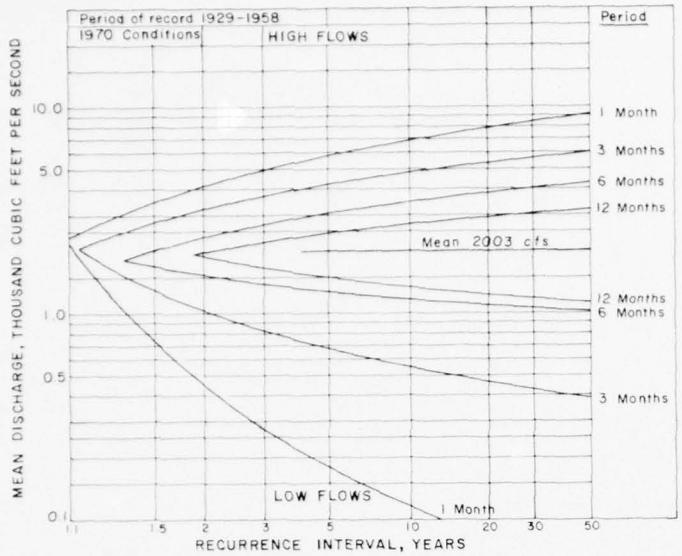


Figure 144 Frequency curves, Chelan River at Chelan

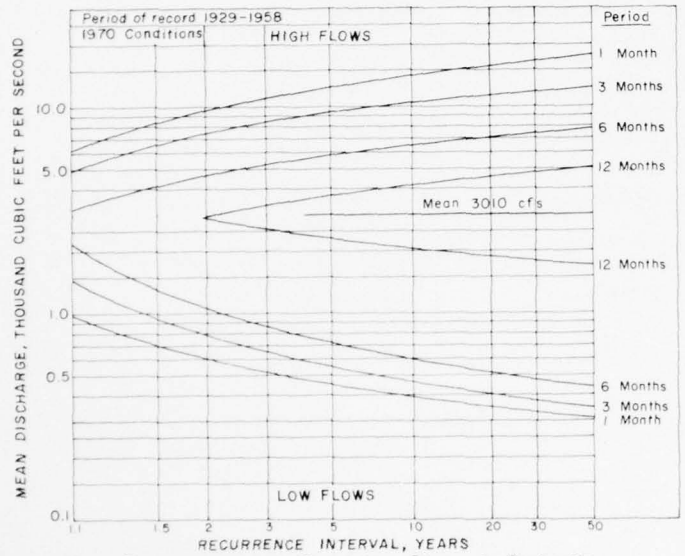


Figure 145 Frequency curves, Wenatchee River at Peshastin

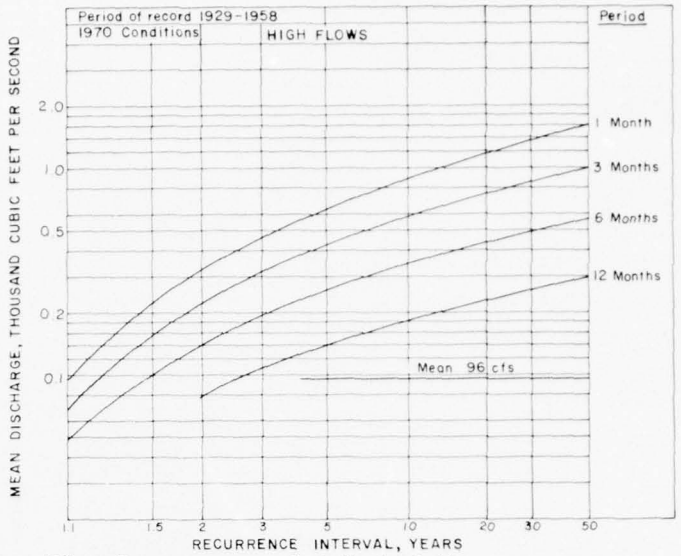


Figure 146 Frequency curves, Crab Creek at Irby

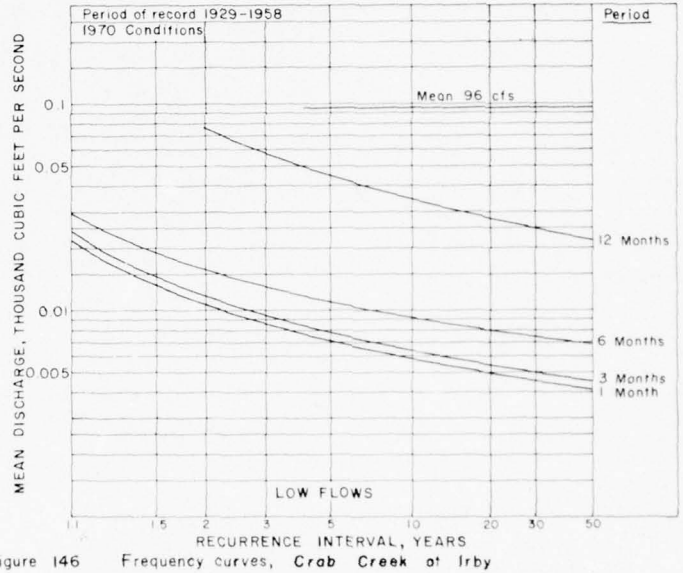


Figure 146 Frequency curves, Crab Creek at Irby

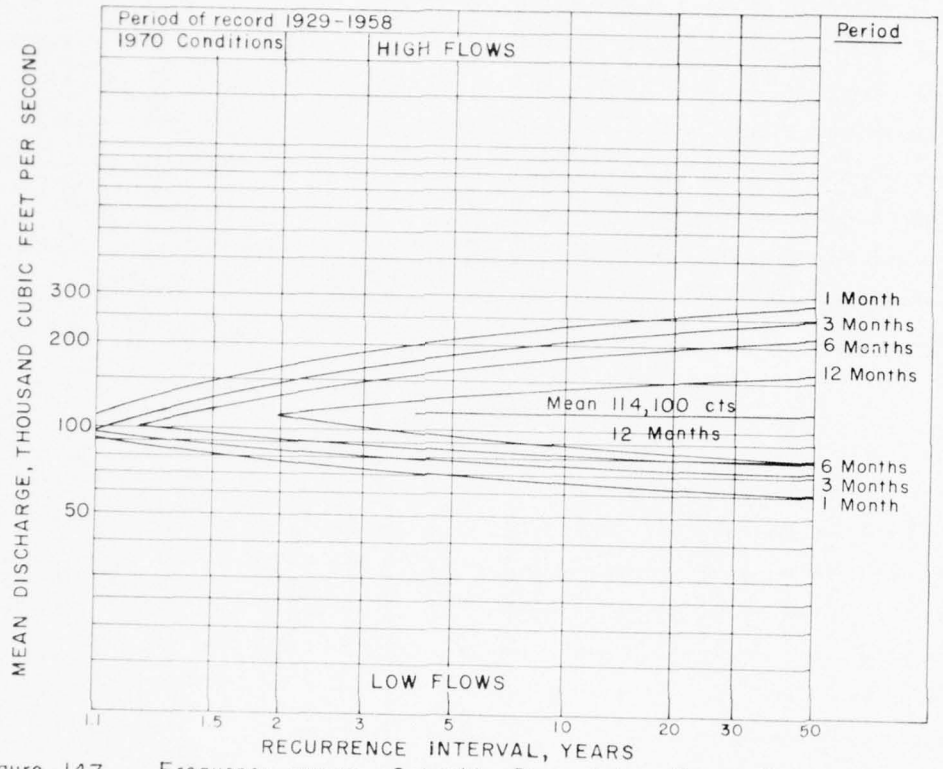


Figure 147 Frequency curves, Columbia River below Priest Rapids Dam

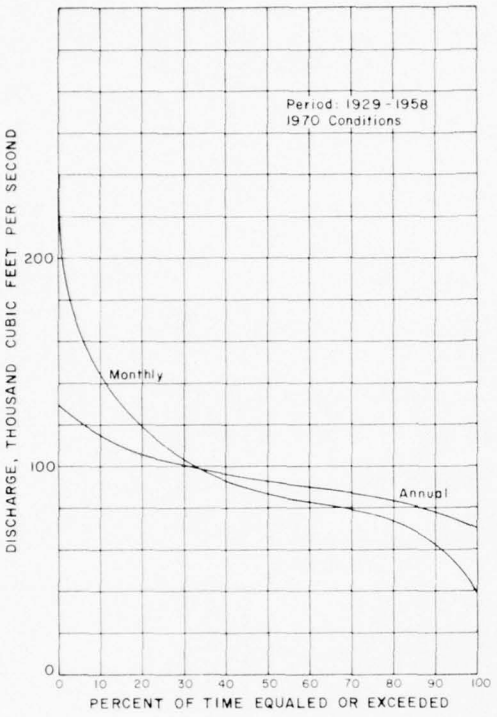


Figure 148 Duration curves, Columbia River at International Boundary

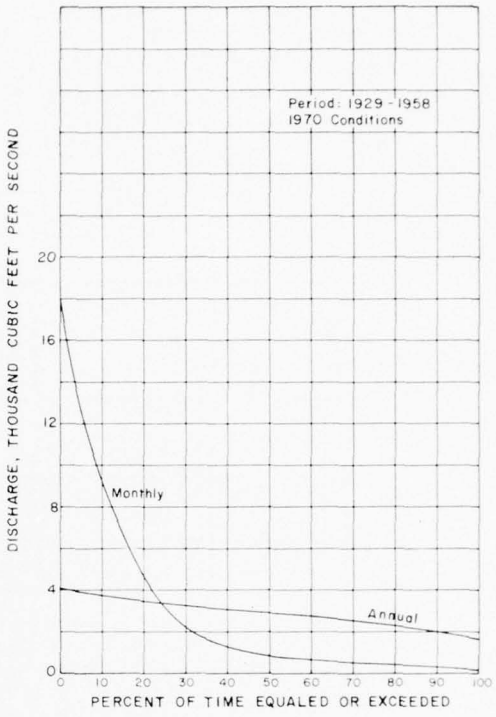


Figure 149 Duration curves, Kettle River near Laurier

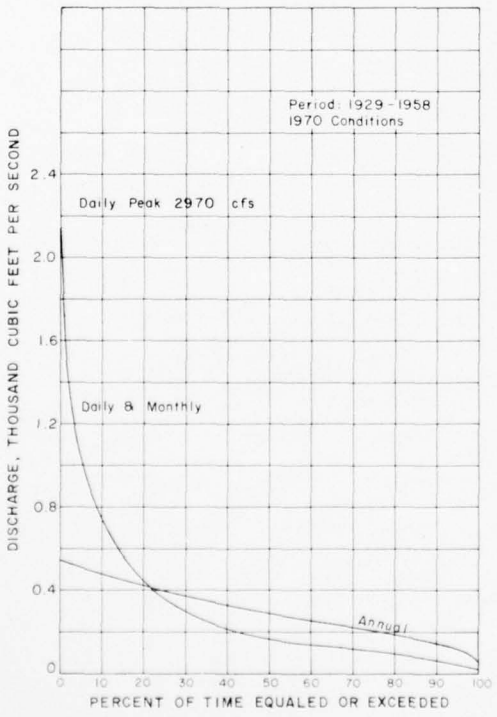


Figure 150 Duration curves, Colville River at Kettle Falls

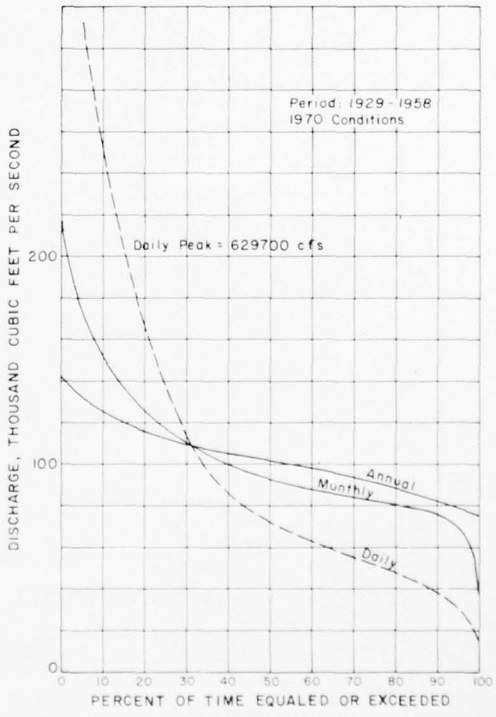


Figure 151 Duration curves, Columbia River at Grand Coulee Dam

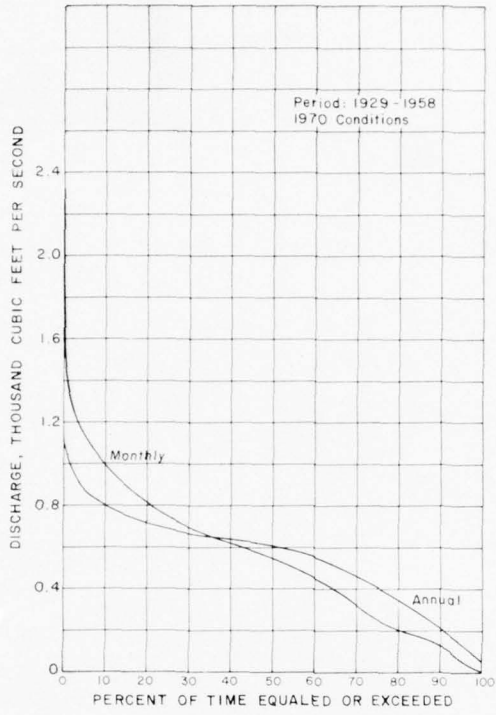


Figure 152 Duration curves, Okanagan River at Okanagan Falls, B.C.

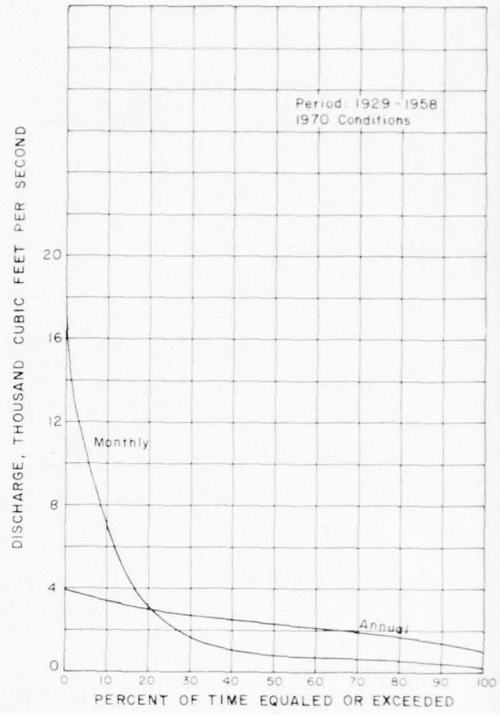


Figure 153 Duration curves, Similkameen River near Nighthawk

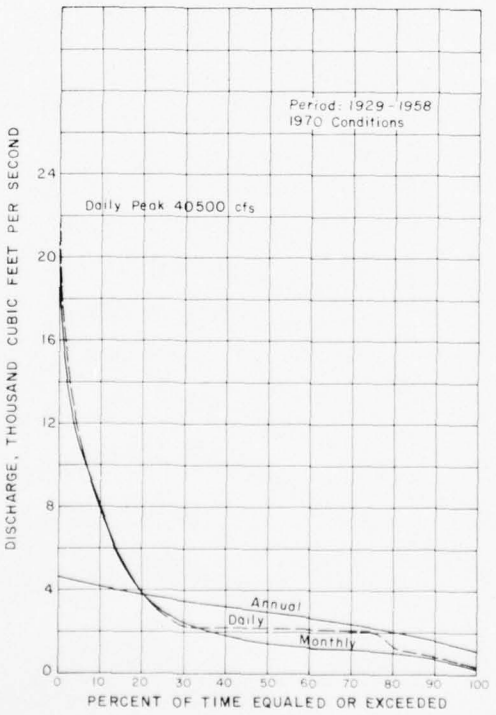


Figure 154 Duration curves, Okanagan River near Tonasket

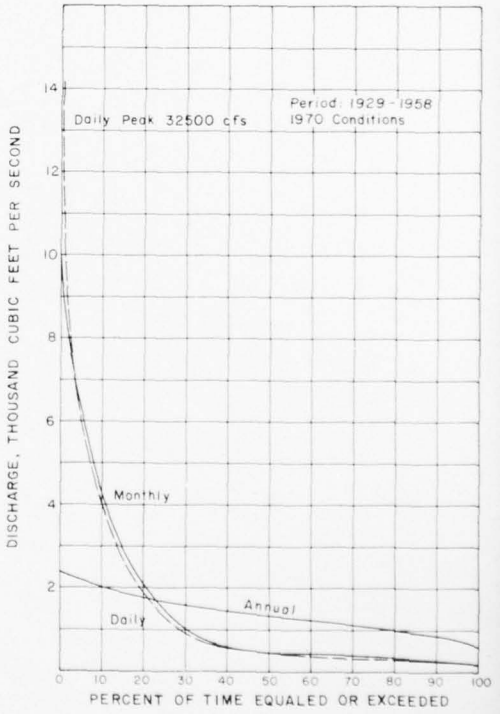


Figure 155 Duration curves, Methow River at Twisp

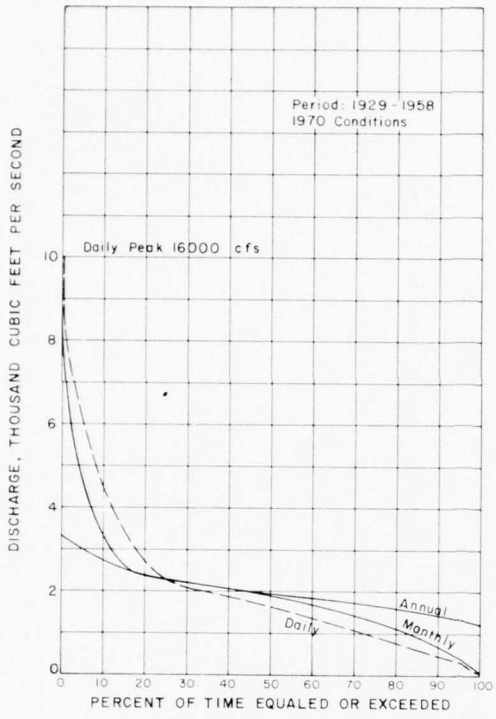


Figure 156 Duration curves, Chelan River at Chelan

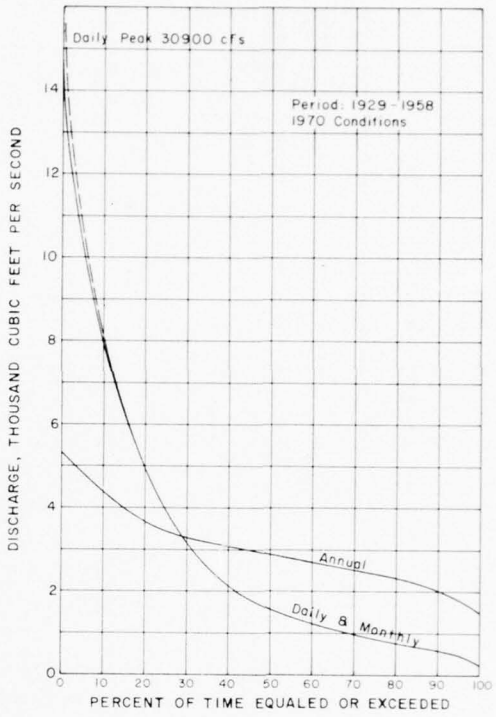


Figure 157 Duration curves, Wenatchee River at Peshastin

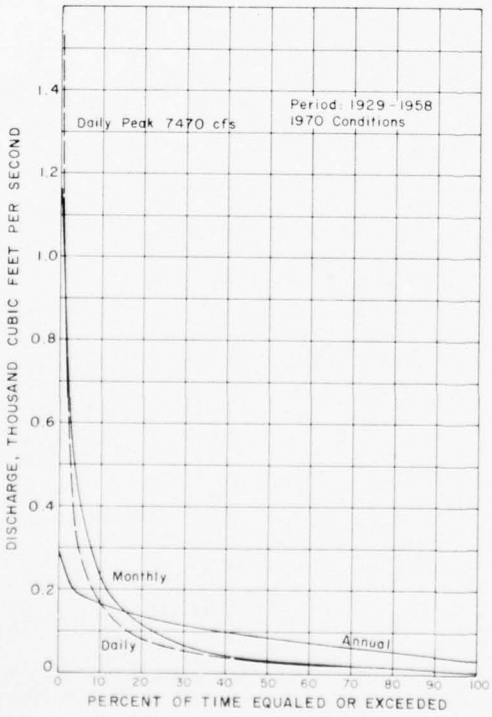


Figure 158 Duration curves, Crab Creek at Irby

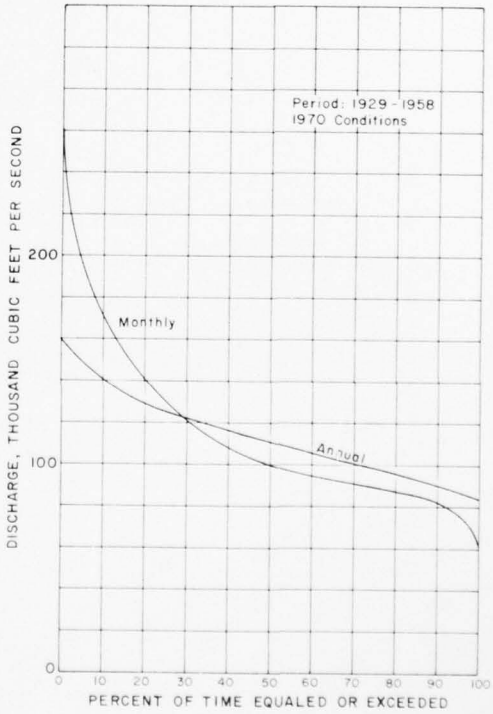


Figure 159 Duration curves, Columbia River below Priest Rapids Dam

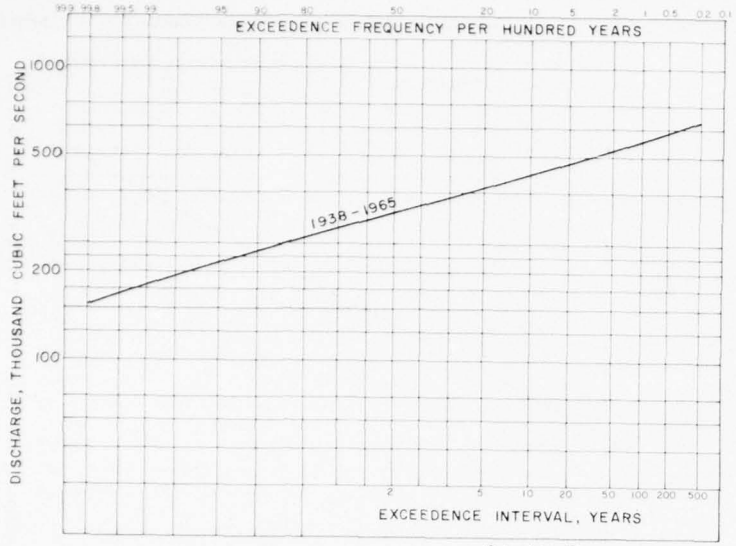


Figure 160 Frequency curve of annual peak flows, at International Boundary

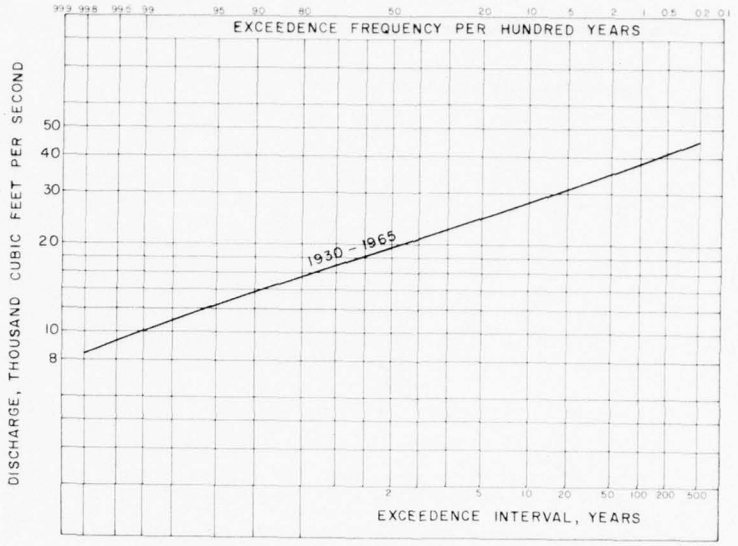


Figure 161 Frequency curve of annual peak flows, Kettle River near Laurier

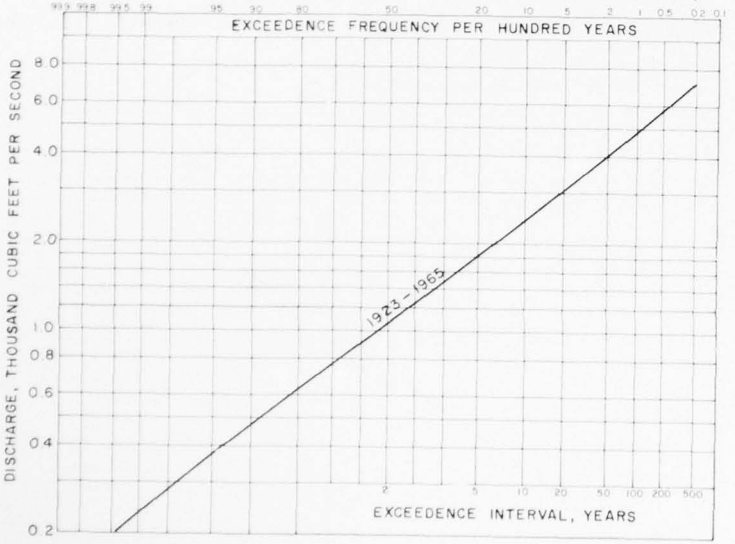


Figure 162 Frequency curve of annual peak flows, Colville River at Kettle Falls

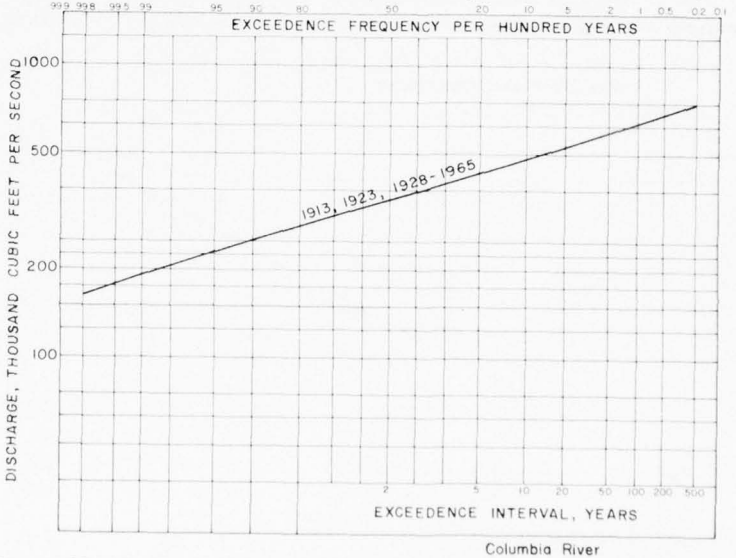


Figure 163 Frequency curve of annual peak flows, at Grand Coulee Dam

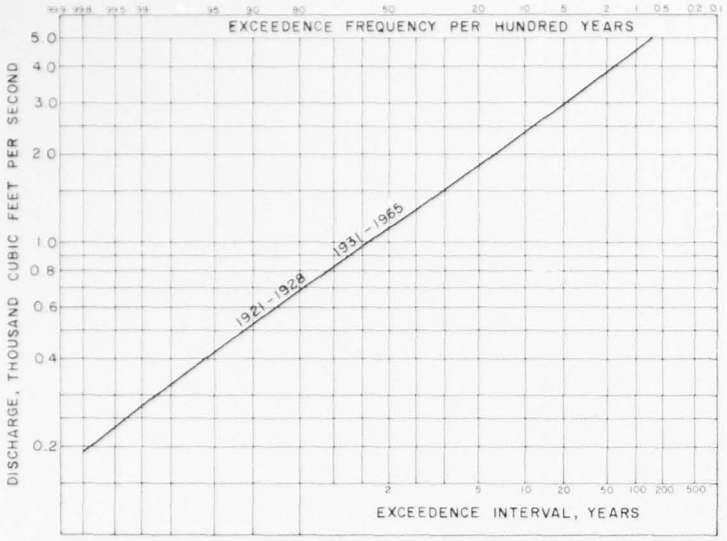


Figure 164 Frequency curve of annual peak flows, Okanagan River at Okanagan Falls, B.C.

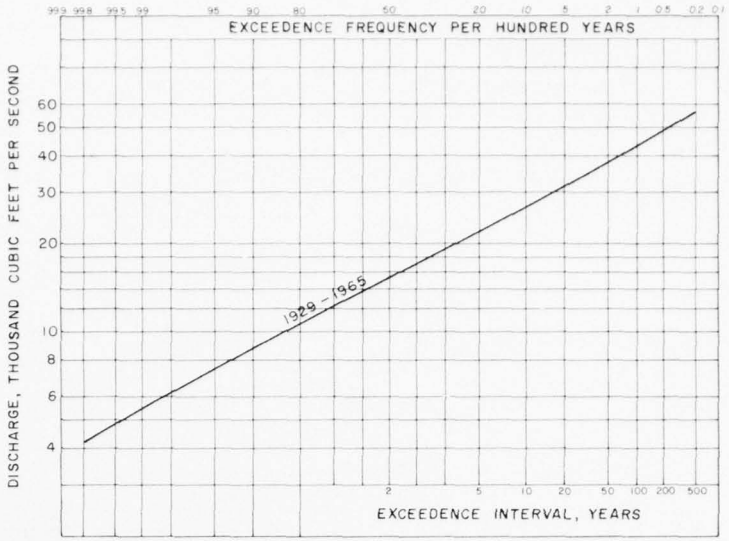


Figure 165 Frequency curve of annual peak flows, Similkameen River near Nighthawk

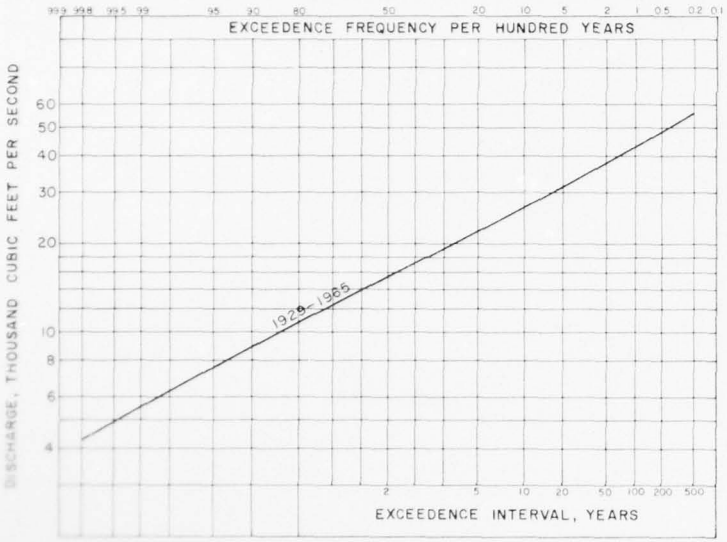


Figure 166 Frequency curve of annual peak flows, Okanogan River near Tonasket

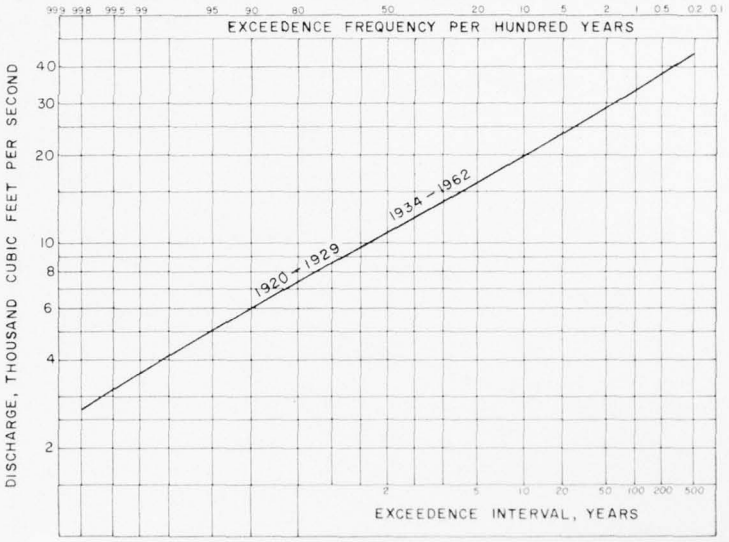


Figure 167 Frequency curve of annual peak flows, Methow River at Twisp

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COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
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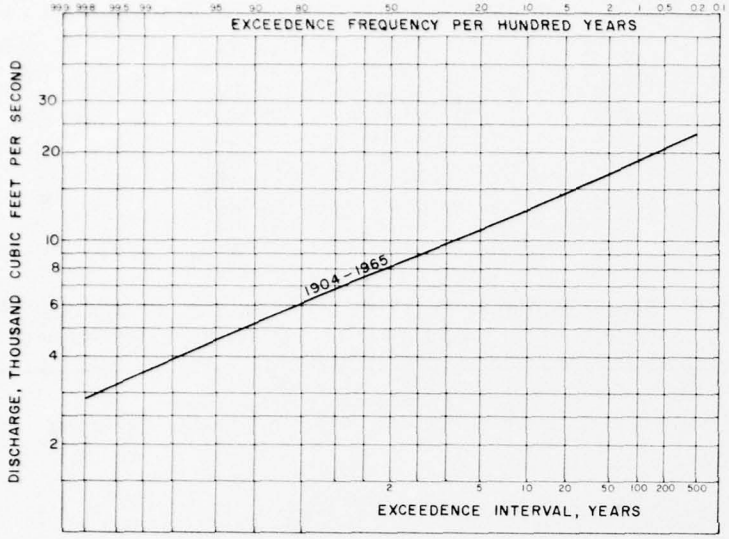


Figure 168 Frequency curve of annual peak flows, Chelan River at Chelan

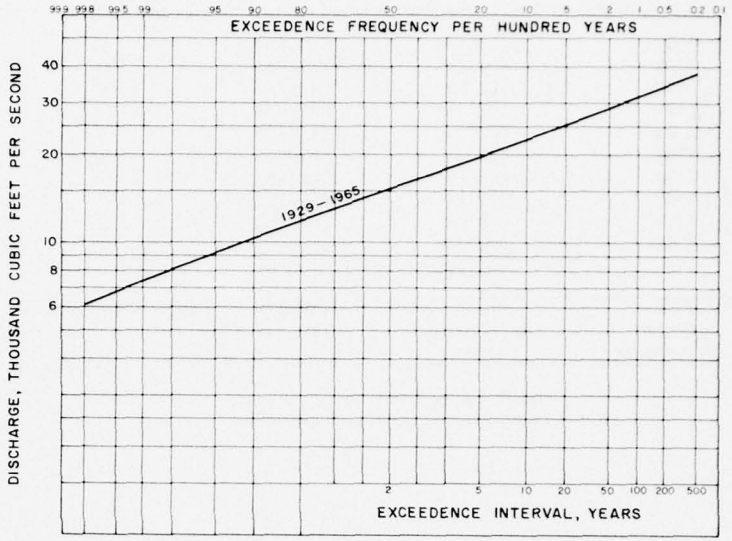


Figure 169 Frequency curve of annual peak flows, Wenatchee River at Peshastin

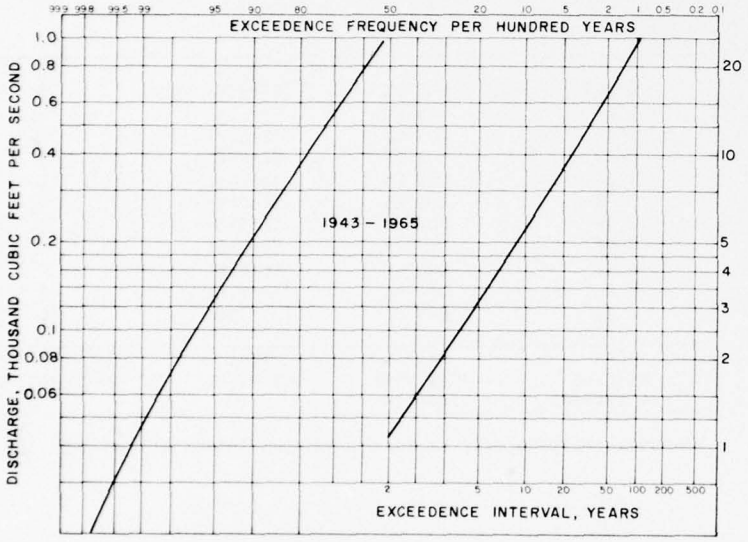


Figure 170 Frequency curve of annual peak flows, Crab Creek at Irby

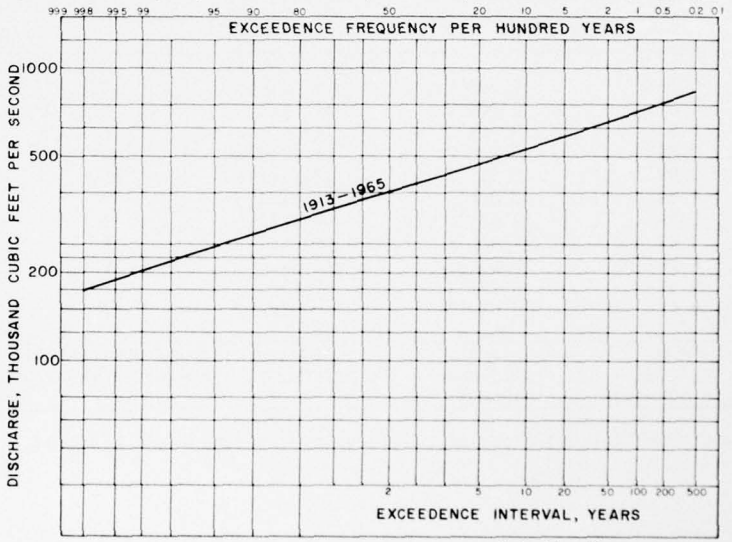


Figure 171 Frequency curve of annual peak flows, Columbia River below Priest Rapids Dam

Table 83. Dependable Yield, Columbia River at International Boundary

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1945	72,500	75.7
2	1944-45	76,200	79.5
3	1944-46	80,200	83.7
4	1942-45	83,200	86.8
5	1941-45	82,600	86.2
6	1940-45	83,000	86.6
7	1949-46	83,800	87.5
8	1938-45	84,200	87.9
9	1937-45	83,300	87.0
10	1937-46	83,800	87.5
30	1929-58	95,800	100.0

Table 84. Dependable Yield, Kettle River near Laurier, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1931-58 Mean
1	1931	1,699.7	58.5
2	1943-44	2,161.0	74.4
3	1935-37	2,407.0	82.9
4	1937-40	2,426.4	83.5
5	1937-41	2,447.0	84.2
6	1936-41	2,478.0	85.3
7	1935-41	2,511.3	86.5
8	1937-44	2,585.7	89.0
9	1936-44	2,591.0	89.2
10	1935-44	2,606.0	89.7
28	1931-58	2,904.6	100.0

Table 85. Dependable Yield, Colville River at Kettle Falls, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	74.7	25.0
2	1930-31	76.5	25.6
3	1929-31	101.2	33.8
4	1929-32	149.7	50.1
5	1929-33	174.1	58.2
6	1929-34	201.1	67.2
7	1929-35	215.3	72.0
8	1929-36	209.4	70.0
9	1929-37	202.8	67.8
10	1929-38	231.2	77.3
30	1929-58	299.1	100.0

Table 86. Dependable Yield, Columbia River at Grand Coulee Dam, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1937	80,300	77.3
2	1944-45	82,100	79.0
3	1929-31	85,800	82.6
4	1929-32	88,700	85.4
5	1941-45	89,600	86.2
6	1940-45	89,900	86.5
7	1939-45	90,700	87.3
8	1937-44	91,500	88.1
9	1937-45	90,300	86.9
10	1936-45	91,000	87.6
30	1929-58	103,900	100.0

Table 87. Dependable Yield, Okanagan River at Okanagan Falls, B.C.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	52.2	9.5
2	1930-31	67.4	12.3
3	1930-32	150.7	27.4
4	1930-33	264.6	48.2
5	1929-33	345.9	63.0
6	1939-44	377.2	68.7
7	1939-45	393.9	71.7
8	1938-45	414.0	75.4
9	1937-45	429.0	78.1
10	1936-45	449.0	81.8
30	1929-58	549.0	100.0

Table 88. Dependable Yield, Similkameen River near Nighthawk, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1930-58 Mean
1	1941	1,092.1	47.1
2	1940-41	1,216.2	52.5
3	1939-41	1,386.9	59.8
4	1939-42	1,634.8	70.5
5	1937-41	1,699.0	73.3
6	1939-44	1,744.2	75.3
7	1939-45	1,776.1	76.6
8	1937-44	1,850.0	79.8
9	1937-45	1,863.1	80.4
10	1936-45	1,877.4	81.0
29	1930-58	2,317.6	100.0

Table 89. Dependable Yield, Okanogan River near Tonasket, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1930-58 Mean
1	1931	1,240.6	42.5
2	1930-31	1,399.2	47.9
3	1930-32	1,620.4	55.5
4	1930-33	1,932.4	66.2
5	1937-41	2,089.8	71.6
6	1939-44	2,173.9	74.5
7	1939-45	2,221.8	76.1
8	1938-45	2,345.4	80.3
9	1937-45	2,339.6	80.1
10	1936-45	2,374.4	81.3
29	1930-58	2,919.2	100.0

Table 90. Dependable Yield, Methow River at Twisp, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1929	681.0	49.5
2	1929-30	802.2	58.3
3	1929-31	799.6	58.1
4	1929-32	874.3	63.5
5	1929-33	954.1	69.3
6	1939-44	1,075.7	78.2
7	1939-45	1,071.0	77.8
8	1939-46	1,124.2	81.7
9	1937-45	1,126.9	81.9
10	1936-45	1,120.4	81.4
30	1929-58	1,375.9	100.0

Table 91. Dependable Yield, Chelan River at Chelan, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percentage of 1929-58 Mean
1	1930	1,278.9	63.9
2	1929-30	1,330.0	66.4
3	1929-31	1,377.4	68.8
4	1929-32	1,502.9	75.0
5	1941-45	1,542.5	77.0
6	1940-45	1,579.7	78.9
7	1939-45	1,583.4	79.1
8	1939-46	1,633.1	81.5
9	1937-45	1,645.7	82.2
10	1936-45	1,668.5	83.3
30	1929-58	2,002.6	100.0

Table 92. Dependable Yield, Wenatchee River at Peshastin, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	1,729.2	56.8
2	1941-42	1,959.0	64.4
3	1940-42	2,133.5	70.1
4	1939-42	2,199.5	72.3
5	1941-45	2,239.0	73.6
6	1940-45	2,279.6	74.9
7	1939-45	2,296.6	75.4
8	1939-46	2,376.1	78.1
9	1937-45	2,392.6	78.6
10	1937-46	2,446.6	80.4
29	1930-58	3,042.2	100.0

Table 93. Dependable Yield, Crab Creek at Irby, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1944-58 Mean
1	1947	30.9	31.5
2	1953-54	40.2	40.9
3	1945-47	47.8	48.7
4	1944-47	47.9	48.8
5	1944-48	66.2	67.4
6	1944-49	81.4	82.9
7	1944-50	93.2	94.9
8	1944-51	96.8	98.6
9	1945-53	94.8	96.5
10	1945-54	89.3	90.9
15	1944-58	90.2	100.0

Table 94. Dependable Yield, Columbia River below Priest Rapids Dam, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1937	86,600	75.9
2	1930-31	89,900	78.8
3	1929-31	92,900	81.4
4	1929-32	95,800	84.0
5	1937-41	96,400	84.5
6	1937-42	97,300	85.3
7	1936-42	98,400	86.2
8	1937-44	99,000	86.8
9	1937-45	97,900	85.8
10	1936-45	98,600	86.4
30	1929-58	114,100	100.0

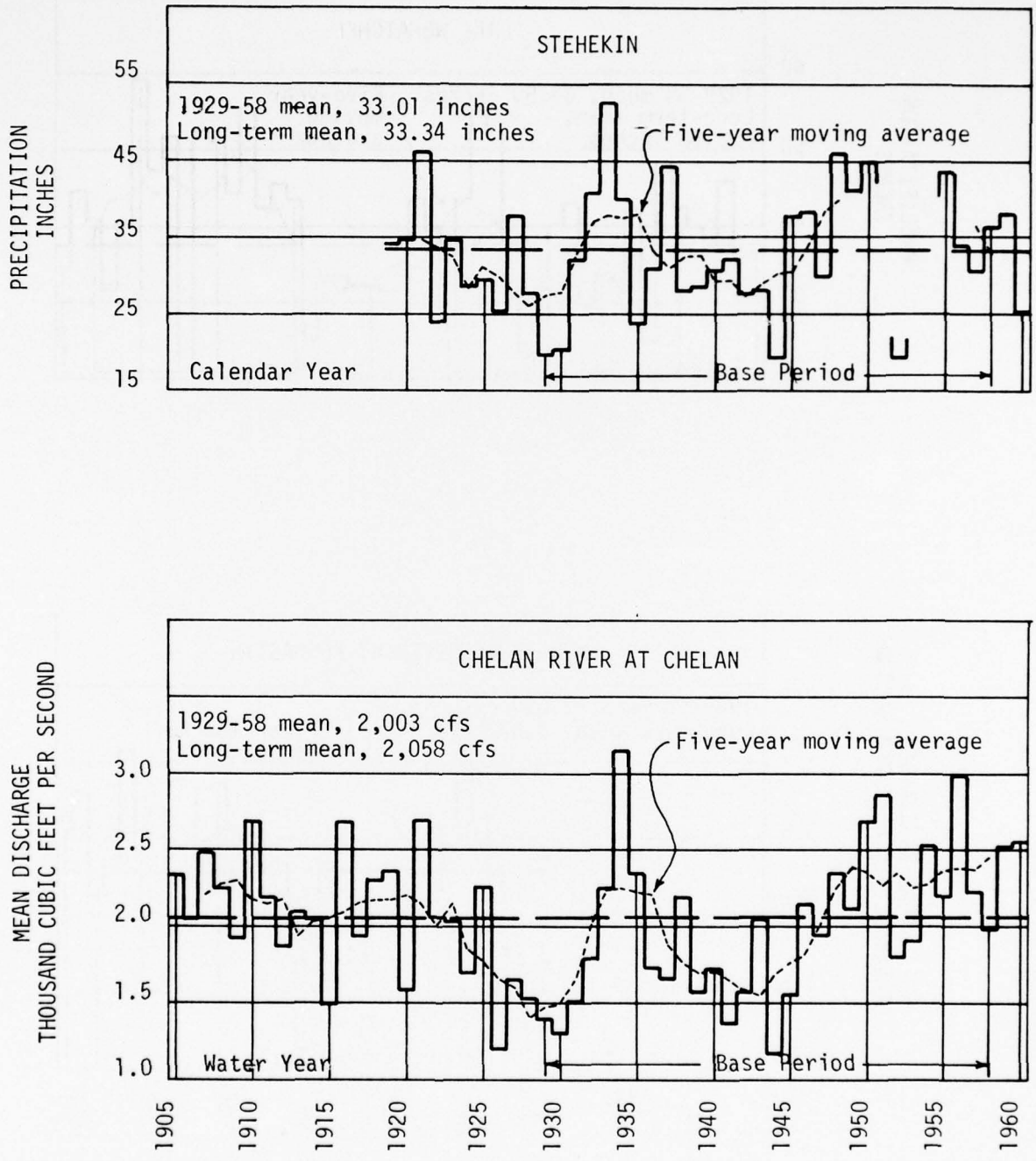


FIGURE 172. Long-term variation in precipitation and streamflow

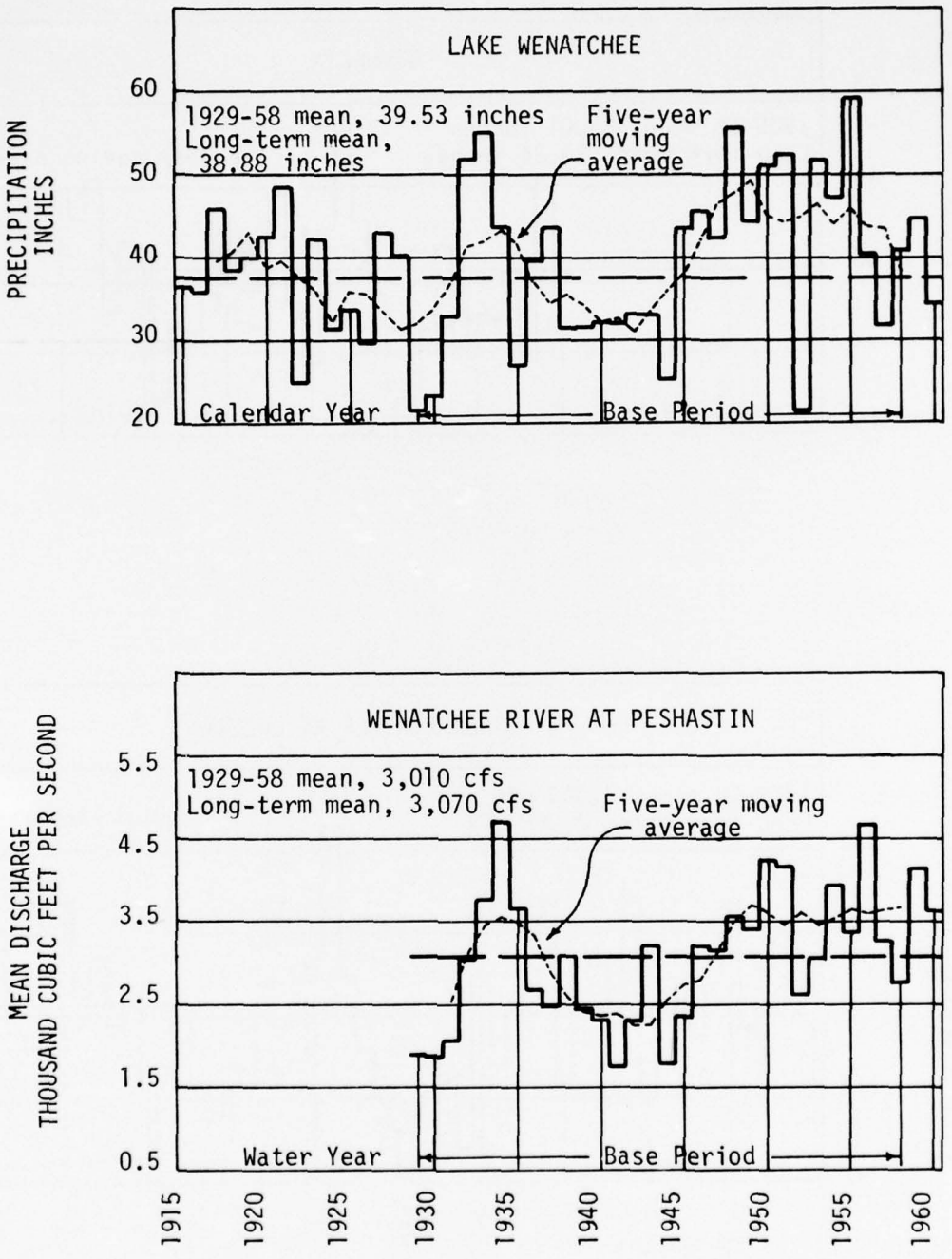


FIGURE 173. Long-term variation in precipitation and streamflow

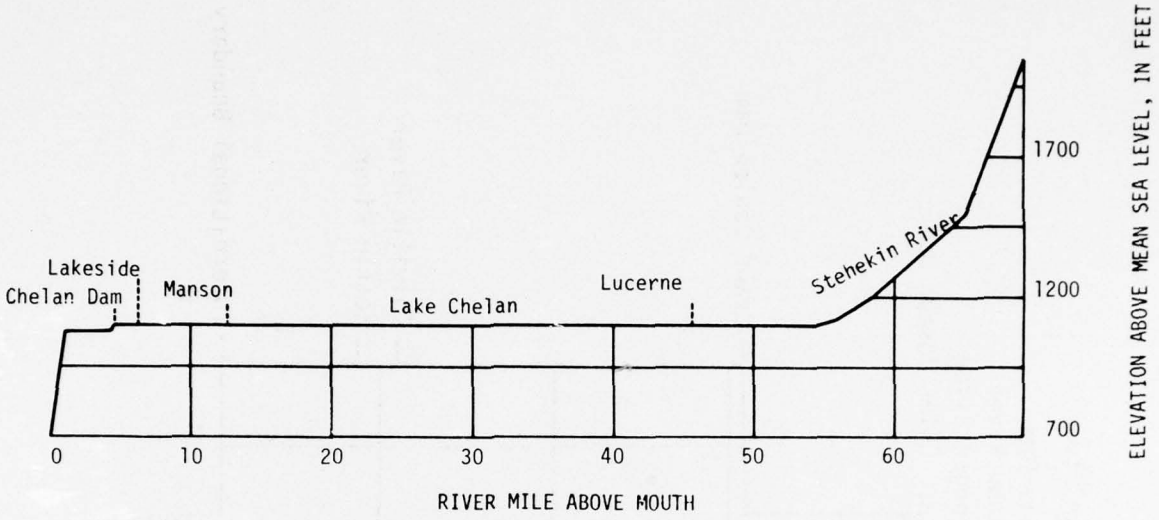


FIGURE 175. Stream Profile, Wenatchee River

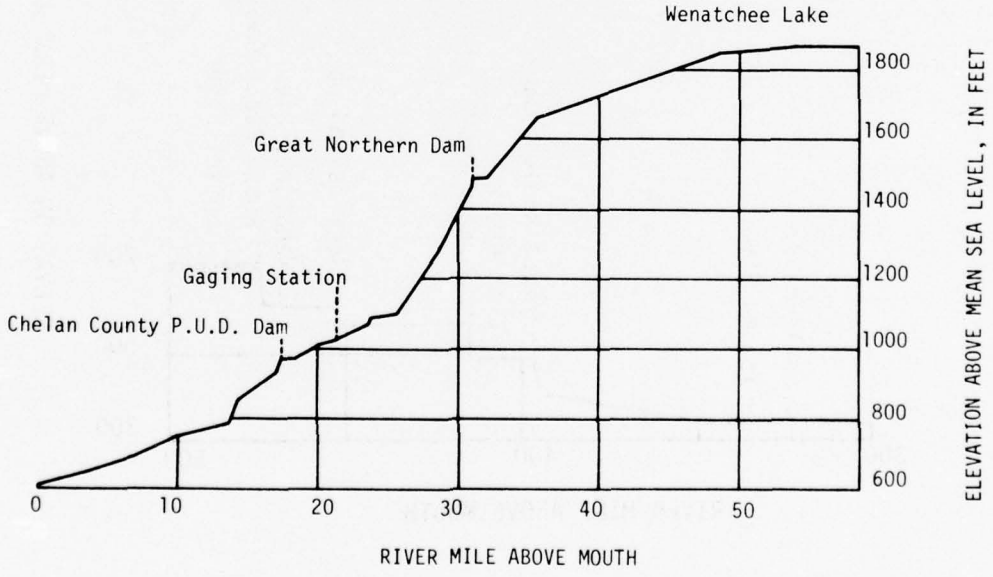


FIGURE 174. Profile, Chelan River, Lake Chelan and Stehekin River

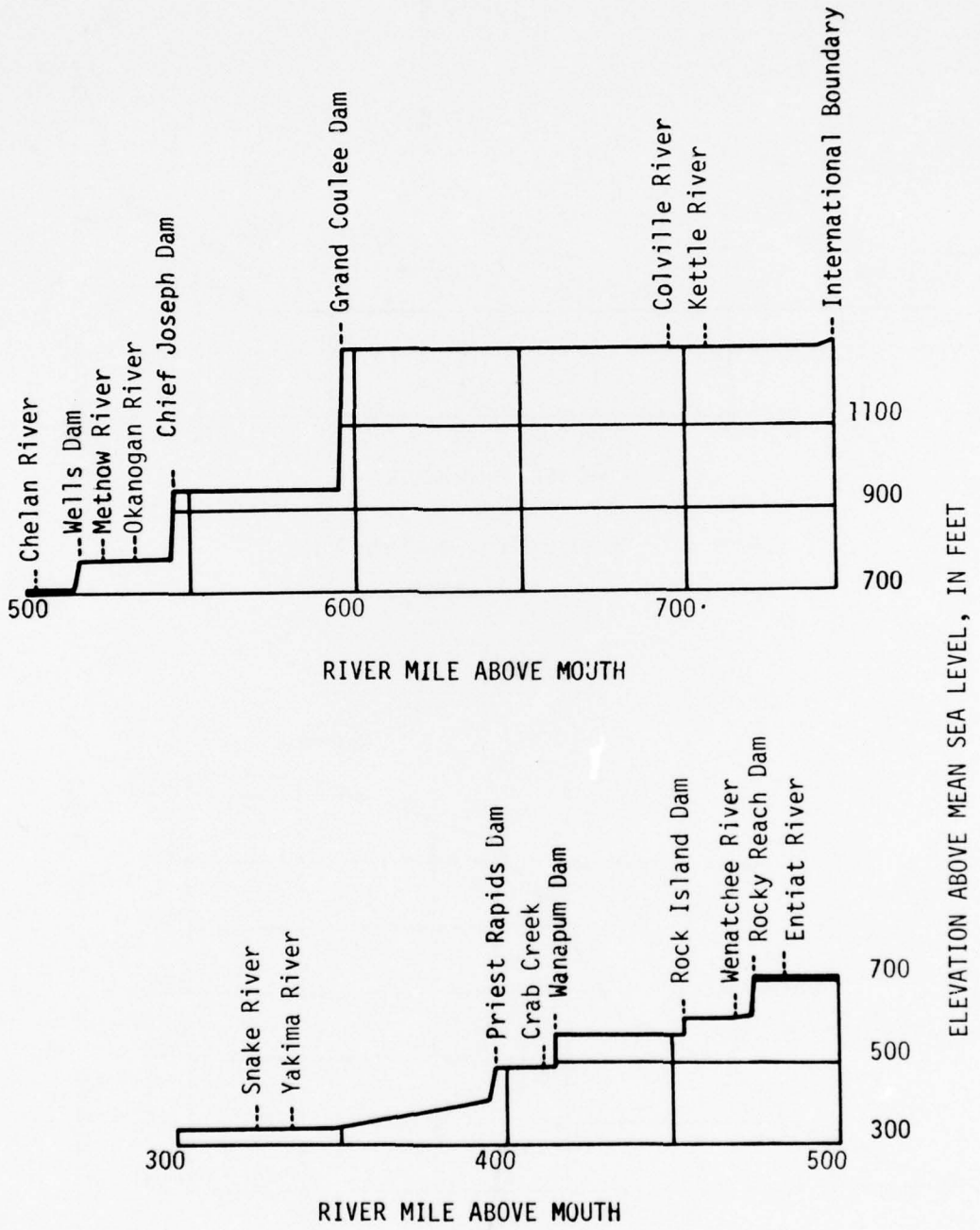


FIGURE 176. Stream profile, Columbia River

Quality

The quality of water in Subregion 2 is generally good. Detailed data are presented on the following pages.

Chemical

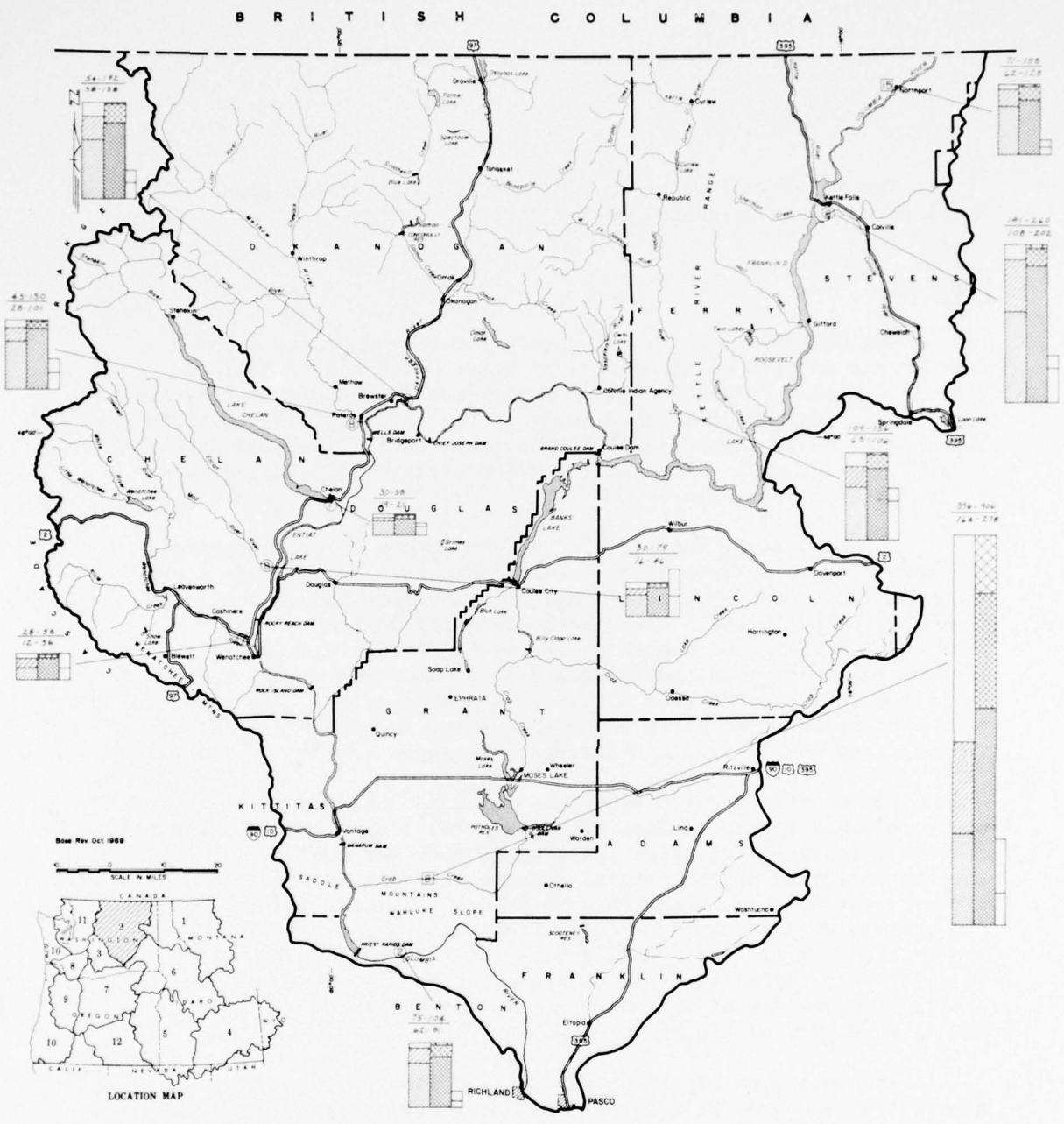
The Columbia River as it enters the United States from Canada is a calcium bicarbonate type water which has an average dissolved-solids concentration of approximately 90 mg/l (milligrams per liter). Samples collected daily at the International Boundary (Northport, Washington) since 1952 have had a dissolved-solids range of 71-158 mg/l. The water is moderately hard, ranging from 62 to 128 mg/l hardness.

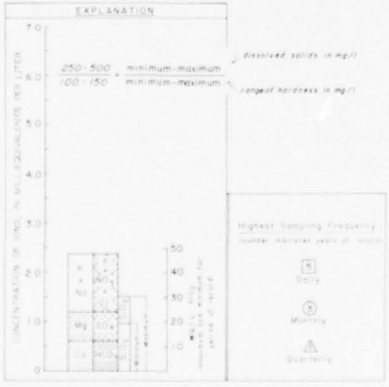
The Wenatchee, Entiat, Chelan, and Methow Rivers entering the upper Columbia River from the west originate in the high elevations of the Cascade Mountain Range where average annual precipitation exceeds 50 inches. The dissolved-solids content of the Wenatchee, Entiat, and Chelan Rivers averages less than 60 mg/l. The maximum observed dissolved-solids concentration was 79 mg/l for a sample collected from Entiat River near Entiat. The dissolved-solids content of the Methow River is slightly greater, ranging from 45-130 mg/l and averaging 94 mg/l.

Those streams which drain the north and east areas of the upper Columbia River are more highly mineralized, primarily because of more extensive irrigation but also because the land is arid and the concentration of the natural solutes is greater. For these streams, the Sanpoil, Okanogan, and Colville Rivers, and Crab Creek, the average dissolved-solids concentration is greater than 125 mg/l and in the case of Crab Creek, greater than 500 mg/l. The water of these tributaries is the calcium magnesium bicarbonate type and has a larger percentage of sulfate than those tributaries which drain the western part of the basin (figure 177).

The main stem of the Columbia River shows little change in mineralization from the International Boundary to the point of its confluence with the Snake River. The effect of incoming tributaries with higher mineralization is partly offset by the contribution of tributaries with lower mineralization. However, the major reason for the uniformity of mineralization in this stretch of the main stem is the relative discharge of the Columbia River compared to that of its tributaries. The average flow of the largest tributary, Spokane River, is less than 10 percent of the average flow of the Columbia River at Pasco.

Colville River and Crab Creek have average dissolved-solids concentrations considerably higher than the Columbia River, but





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CHEMICAL COMPOSITION OF WATER

UPPER COLUMBIA SUBREGION 2

1968

FIGURE 177

their combined average discharge is less than 500 cfs compared to more than 100,000 cfs for the Columbia River.

Although some of the streams have been subjected to extensive irrigation use, their suitability for additional irrigation or other domestic or industrial uses has not been impaired. The water of most streams would meet drinking water standards with minimum treatment.

Biological-Biochemical

Dissolved oxygen concentrations in the rivers and streams of this subregion are normally near saturation at almost all locations. Occasional dips do occur seasonally, but do not constitute any significant impairment of water quality. Oxygen levels near the bottom of Moses Lake, determined in the summer of 1963, range from 2.7 - 7.3 mg/l, apparently due to the oxygen demand of intense algal growths in the lake. Dissolved oxygen concentrations and coliform densities determined through the data collection program of the State of Washington and USGS are summarized in table 95. Intensive survey information for the Columbia Basin Project collected by the Public Health Service is also available. Coliform densities vary widely through the subregion and, as indicated in the table, do reach levels below many communities which render water courses unsuitable for water contact sports. However, these adverse conditions are localized and do not indicate a widespread problem. It is believed that high coliform densities occurring in the lower reaches of Crab Creek are attributable in large part to cattle

Table 95 - Dissolved Oxygen & Coliform Organisms Densities
Upper Columbia Subregion

Location	Dissolved Oxygen mg/l			Coliform Organisms /100 ml		
	Mean	Min.	Max.	Mean	Min.	Max.
Columbia R. at Northport	12.1	8.6	16.8	68	0	230
Kettle R. nr. Barstow	11.2	7.9	14.5	602	0	11,000
Colville R. at Kettle Falls	10.5	7.3	13.8	4,775	0	46,000
Sanpoil R. at Keller	11.1	7.8	13.6	901	0	11,000
Okanogan R. at Oroville	11.0	8.4	13.2	52	0	430
Similkameen R. at Oroville	11.0	8.2	14.5	99	0	930
Okanagan R. at Brewster	10.9	5.8	15.4	4,699	0	240,000
Methow R. at Pateros	11.5	9.3	14.2	457	0	9,300
Chelan R. at Chelan	10.5	8.6	12.1	259	0	2,400
Entiat R. nr. Entiat	11.8	8.9	14.2	775	0	11,000
Wenatchee R. nr. Leavenworth	10.9	4.2	13.6	677	0	24,000
Wenatchee R. at Wenatchee	11.9	9.1	16.4	1,047	0	11,000
Crab Creek at Irby	11.6	9.0	13.6	738	36	2,900
Crab Creek at Moses Lake	12.1	9.7	16.0	20,445	0	230,000
Crab Creek at Smyrna	11.1	6.6	16.6	1,780	0	24,000
Crab Creek nr. mouth	11.5	9.5	13.2	650	0	2,100
Columbia R. below Priest Rapids	11.8	9.5	14.0	131	0	430

pastured on adjacent land. Algal growths, interfering with recreational use of Moses Lake, result from abundant nutrient input to the lake. This nutrient load is derived from both natural and manmade sources. In addition to esthetically degrading quality, these organisms also exert a significant demand on the oxygen resources of the lake.

The Columbia River below Hanford Works has a mean beta count of 583 pc/l. The maximum level has not exceeded 1,000 pc/l since November 1964. Levels of zinc -65 and phosphorus -32 approximate 100-200 pc/l in the Columbia River below Hanford.

Sediment

No suspended-sediment concentration data have been collected recently in the subregion. A few samples (17) were obtained in the 1905-11 period and at two sites in 1951-52. The 1951-52 data are unpublished. A reservoir sedimentation survey was made on Wilson Creek in the Crab Creek Basin in 1936. Figure 178 (30) shows that sediment yield in the region ranges between 0.02 and 1.5 acre-feet per square mile per year with the greatest yield from the agricultural areas, mostly from dry farmland. The largest sediment yields, such as near Douglas Creek, are caused either by erosion of the surface soil when the underlying ground is frozen or by high-intensity rain storms in the summer months. (30)

Water Temperature

Water temperature data are somewhat limited in Subregion 2. Until recently the regular collection of data was made at only one station selected for detailed analysis, Columbia River at International Boundary. Some data are available for the Columbia River at Grand Coulee Dam. At the present time data are being obtained for five points on the Columbia River--at International Boundary at Northport, below Grand Coulee, Chief Joseph, Rock Island, and Priest Rapids Dams--and above Richland. Thermographs are installed at three of these locations. Data are also available for a short period of record for Similkameen River at Nighthawk, Washington. Water temperature data for the first two named stations are presented in figure 179. The means should be representative of the long-term means even though it is recognized that the longer the record the greater the spread between maximum and minimum water temperatures. The range of the mean July temperature for the Columbia River at International Boundary is 56°F. to 62°F. The maximum July water temperature ranged from 55°F. to 66°F. and the mimimum from 52°F. to 58°F.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERALIZED SEDIMENT YIELD

UPPER COLUMBIA SUBREGION 2

1968

FIGURE 178

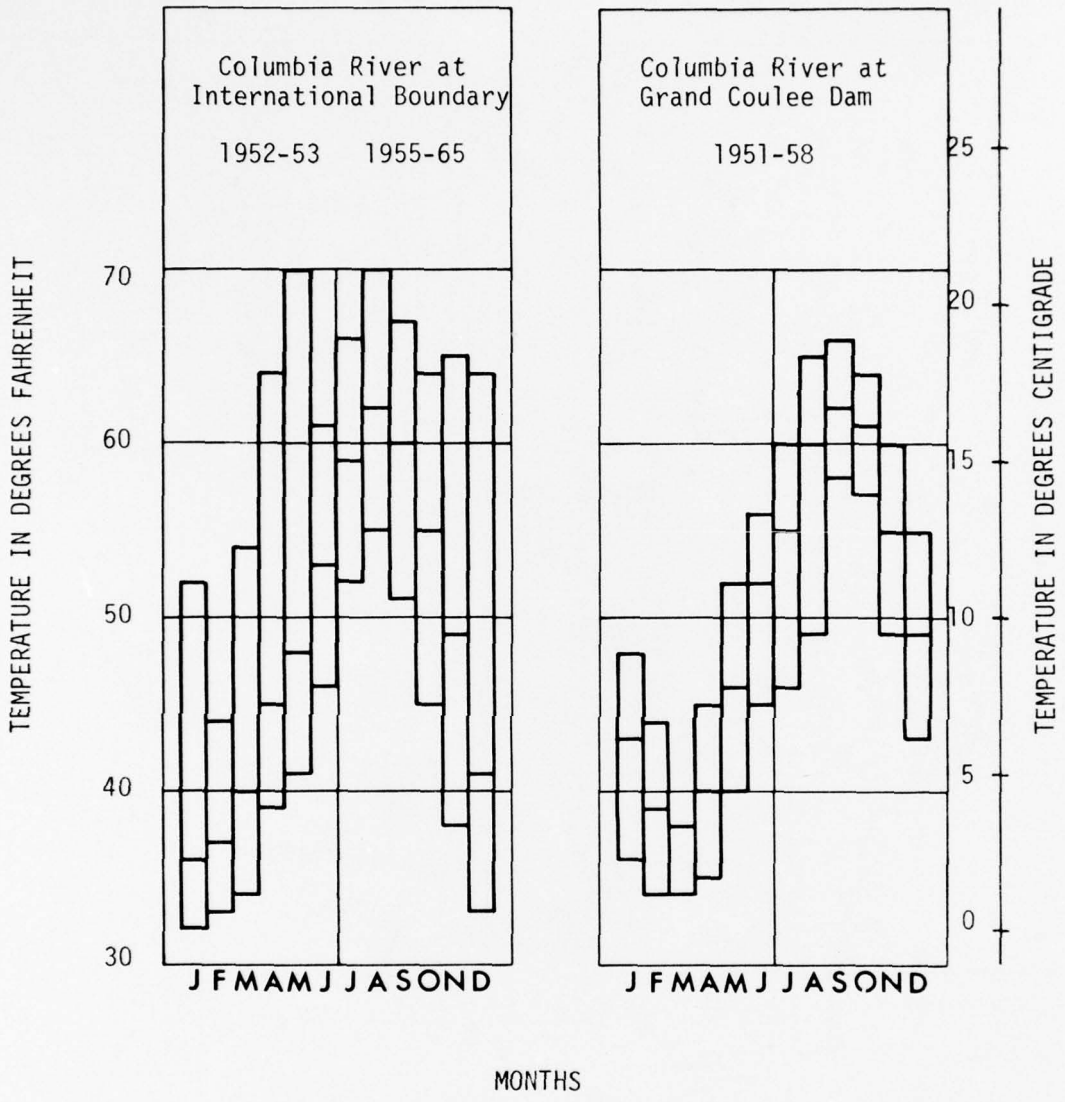


FIGURE 179. Monthly water temperatures for selected stations. Top, middle and bottom bars represent maximum, mean, and minimum temperatures.

GROUND WATER

There are two major aquifer units in Subregion 2 that yield large supplies of water to wells. Quaternary alluvial and glacial deposits (Qg) are the most important north and northwest of the Columbia River; basalt of the Columbia River group (Tcr) is the most important south of the Columbia River. Both aquifer units are capable of supporting much larger development at many places. The other three aquifer units delineated generally will yield only small to moderate supplies. The ground water is moderately to very hard but otherwise is of good quality in most places.

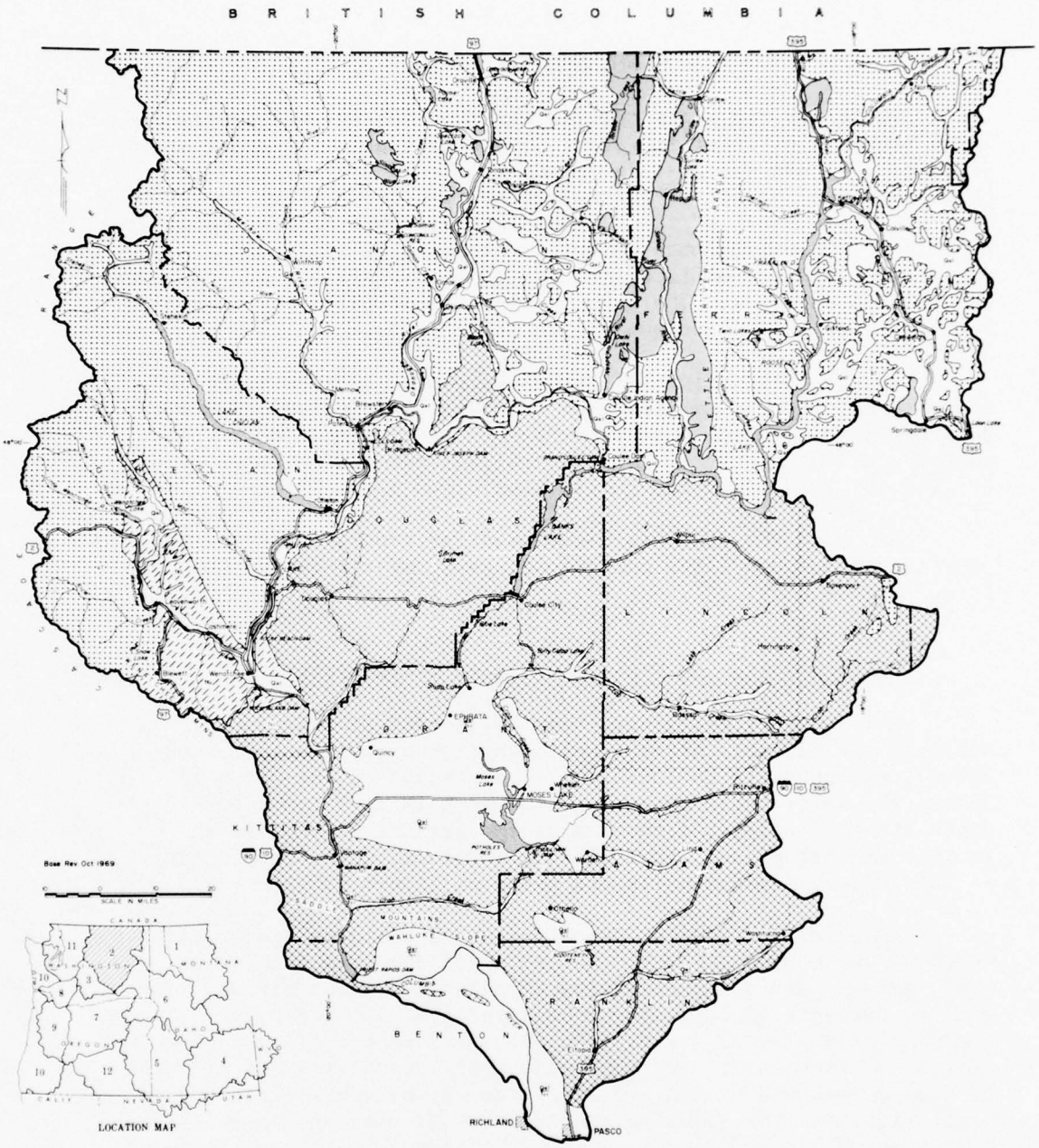
Practically no investigations have been made north of the Columbia River. However, data on file with the Geological Survey and the State Department of Water Resources show that many wells that yield 500 to several thousand gallons per minute have been drilled for irrigation and public supply.

South of the Columbia River, several reports describe the aquifers and ground water conditions, particularly in the Columbia Basin Project area. (27, 84, 87, 98, 103, 157, 191)

Aquifer Units and Their Hydrologic Characteristics

Five aquifer units have been delineated in Subregion 2. North of the Columbia River, aquifer-unit boundaries were based chiefly on the State Geologic Map. (54) South of the Columbia River, the water table in much of the area is at a considerable depth and the geologic formation at the surface may not be an aquifer at that place. Boundaries, therefore, were based largely on well data. Aquifer units are shown on figure 180.

Alluvial and glacial deposits (Qg) are widespread in valleys north of the Columbia River. The alluvial deposits consist of sand, gravel, and silt underlying terraces and flood plains. The glacial deposits include coarse sand and gravel outwash, till, and poorly sorted glacial drift. The glacial lake deposits consist largely of fine sand, silt, and clay, but include some thin lenses of coarse sand and gravel. Most of the deposits have moderate to high porosity. The alluvium and the glacial outwash generally are highly permeable and yields of several hundred to several thousand gallons per minute can be obtained where several tens of feet of clean coarse sand and gravel are saturated. South of the Columbia River the aquifer unit consists chiefly of glacial outwash, but includes the Ringold Formation where it underlies the glacial outwash. Glaciofluvial outwash occurs in the Quincy Basin and Moses Lake areas as widespread sheets and channel deposits. Southward to Pasco it occurs as channel deposits in coulees and broader depressions. Some of the deposits are chiefly large pebbles,



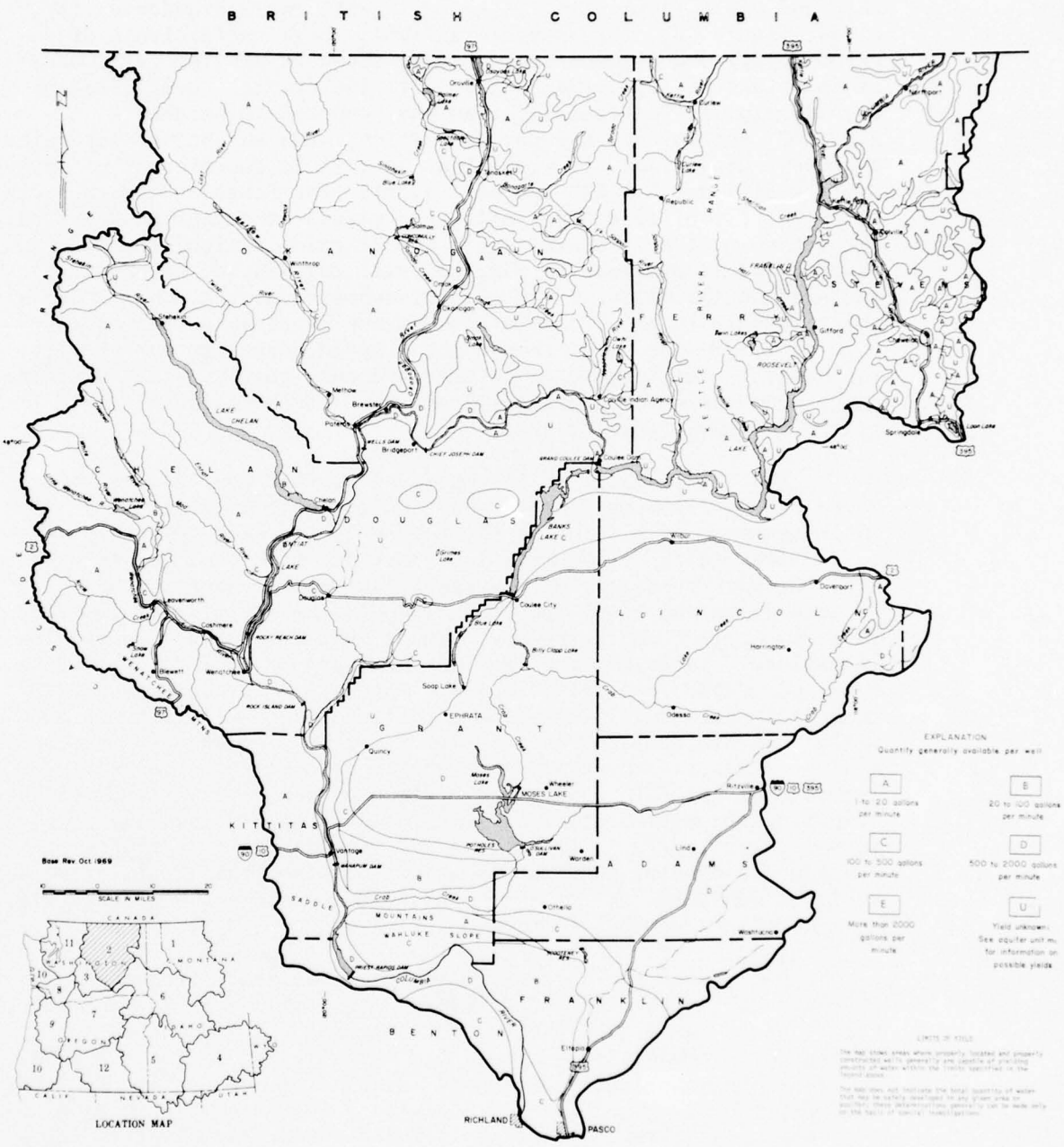
COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

AQUIFER UNITS

UPPER COLUMBIA SUBREGION 2

1968

FIGURE 180



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERAL AVAILABILITY OF GROUND WATER
UPPER COLUMBIA SUBREGION 2

1968

FIGURE 181

cobbles, and boulders. At many places the strata are very permeable and yield large supplies to wells with small drawdowns. (87, p. 44, figure 15) The characteristically high coefficients of permeability and transmissibility are shown by aquifer tests made at Soap Lake in 1953. (84, p. 20, 23) The average coefficient of transmissibility at that location was computed to be about 3.6×10^6 gallons per day per foot which, with an average saturated thickness of 45 feet, is equivalent to a field coefficient of permeability of about 8×10^4 gpd per sq. ft. The Ringold Formation consists chiefly of fine sand, silt, and clay, with minor coarse sand and gravel. At most places where the Ringold is significant as an aquifer, it is overlain by glaciofluvial outwash and has been included in the alluvial and glacial-deposits aquifer unit. Elsewhere, basalt in the Columbia River group is shown as the aquifer unit on figure 180, even though the Ringold Formation may overlie the basalt. The Ringold is thicker and more coarse in the Hanford-Pasco area where it is a significant part of the alluvial and glacial-deposits aquifer unit.

The basalt (Tcr) is an important aquifer nearly everywhere south of the Columbia River. That aquifer unit consists of a thick sequence of widespread flood-type flows, each generally 20 to 100 feet thick. The central 90 percent, more or less, of each flow is massive and nearly impermeable but pillow lava at the base of some flows and rough, broken lava near the top of most individual flows are porous and permeable. Where lava from a succeeding flow incompletely seals the openings in the upper part of the preceding flow, permeable interflow zones are formed. A section of basalt that includes several interflow zones generally will transmit and yield moderate to large quantities of water. Sedimentary interbeds seal openings in the basalt and usually reduce the permeability of interflow zones. In general, the yield of a well is related to the number of saturated interflow zones penetrated and thus indirectly to well depth. (87, p. 41, figure 14) Yields mostly are 1 to 1.5 gpm per foot of penetration below the water table with drawdowns of 20 to 100 feet, except in the Pasco Basin where the average yield is less than 1 gpm per foot of penetration.

The widespread Eolian silt (Qce on the State Geologic Map), commonly called the Palouse Formation or locally the "Palouse Silt," occurs as a veneer over the Columbia River group in much of Subregion 2. Generally, it has high porosity and low permeability. It is not an important aquifer and was not included on the aquifer-unit map. However, at places, especially in the eastern part of the subregion where the deposit is thicker and precipitation is greater, a zone of perched ground water yields small supplies for domestic and stock use.

The Tertiary volcanic-rock aquifer unit (Tv) occurs in several areas north of the Columbia River. No information was available regarding hydrologic characteristics. However, the State Geologic Map shows that much of this unit is of Eocene and Oligocene age. Similar volcanic rocks of those ages in western Oregon and western Washington have low permeabilities and generally yield small supplies to wells. Younger volcanic rocks may be included with this aquifer unit at some places and might be more permeable.

The nonmarine sedimentary strata (TKc) in the northwestern part of the subregion include coarse grained sandstone, arkose, and conglomerate that might yield moderate supplies of water at some places. However, practically no data are available on the hydrologic characteristics of these rocks.

The pre-Tertiary formations (pT) are chiefly metamorphic and granitic and consolidated sedimentary rocks with low porosities and permeabilities. A fairly deep soil and subsoil have developed on them and considerable ground water is stored in this zone. The aquifer unit is important in the regimen of streams draining it and furnishes small supplies to many wells and springs for domestic and stock use.

The descriptions of the aquifer units, their general hydrologic characteristics, and the general quality of the water yielded by them are given in table 96. The general availability of ground water is shown on figure 181. For maximum utility, this figure and the aquifer-unit map, figure 180, should be used together.

Most of the wells in alluvial deposits north of the Columbia River are shallow. Many are small in diameter. It is probable that the yield range shown on figure 181 is low at some places. Properly constructed large diameter wells or infiltration trenches might increase the yields to the next range.

South of the Columbia River a large area is shown in the yield range of "500 to 2,000 gpm." At some places both the glacial deposits (Qg) or the basalt (Tcr) will support wells in that yield range.

As was explained previously, the yield of wells in the Columbia River basalt is related to depth penetrated below the water table. Most irrigation, industrial, and public supply wells are a few hundred to about a thousand feet deep. Yields range generally from several hundred to more than 1,000 gpm. Larger yields could be obtained at most places by drilling deeper. The lower range in yield indicated for the basalt north of Wilbur and Davenport is caused by thinning of the basalt over the northward-rising surface of the underlying pre-Tertiary granite.

Table 96. Description of Aquifer Units and their Hydrologic Characteristics, Subregion 2

Map Symbols and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
Qg: Stream alluvium, glacial drift and fluvio-lacustrine deposits of Pleistocene and Holocene age. Includes Ringold Fm., below Qg, in parts of the Columbia Basin.	Sand, gravel, and silt in terraces and flood plains; glacial outwash ranges from fine sand to boulders. Glacial drift includes till and unstratified, poorly sorted sand and gravel. Glacio-lacustrine deposits are generally clay, silt, and fine sand with some lenses of coarse sand and gravel.	Coarser stream alluvium and glacial-outwash deposits are very porous and permeable; yields of 1,000 gpm to several thousand gallons per minute common. Fine-grained deposits yield little water. Thin lenses of coarser-grained materials are important locally.	Dissolved solids generally 200-400, rarely exceeds 500 mg/l; hardness generally 100-250 mg/l. Fluoride and boron low.
Tcr: Basaltic lava flows and associated clastic and pyroclastic rocks of the Columbia River Group. Upper part is the Yakima Fm.; lower part generally is not exposed, is known only from well logs.	Commonly dark gray basalt, in extensive sheets 20 to 100 feet thick. Center and basal parts generally dense, massive; uppermost part of each flow vesicular and jointed. Thin beds of pyroclastic or water-laid volcanic debris between some flows. Total thickness several thousand feet.	The larger part of each flow has low porosity and permeability. The uppermost few feet of some flows and the zone at contact with the overlying flow frequently porous and permeable. Where several permeable interflow zones are penetrated, wells yield a few hundred to several thousand gallons per minute.	Dissolved solids generally 200-400 mg/l; water soft to very hard. Fluoride usually low. Deeper wells at places yield softer water, higher in sodium and fluoride than more shallow wells.
Tv: Tertiary volcanic rocks; includes Eocene, Oligocene, and Tertiary volcanic rocks, undifferentiated.	Bedded andesite breccia, andesite flow breccia, andesite, basalt and rhyodacite flows, interbedded mud flows, tuff, tuffaceous sandstone and shale, and coarse pyroclastic rocks. Older formations altered and mineralized.	No data available. Rocks of Eocene and Oligocene age probably will yield only small supplies. Miocene and younger lavas and coarse pyroclastics may yield moderate supplies.	No data available. Probably lower in dissolved solids, hardness, and fluoride than water in Tcr.
TKc: Nonmarine sedimentary strata of Paleocene-Cretaceous age.	Brown-gray to light gray, medium to coarse grained, massive cross-bedded arkose with interbedded conglomerate and siltstone.	No data available. Coarse-grained, jointed rocks probably will yield small supplies at most places, moderate supplies at favorable locations.	No data available. Probably calcium magnesium bicarbonate water, low in dissolved solids and moderately hard to hard.
pT: Rocks of pre-Tertiary age; includes Precambrian, Paleozoic, and Mesozoic rocks.	Phyllite, argillite, slate, schist, gneiss, graywacke, quartzite, shale, limestone, dolomite, conglomerate, sandstone; greenstone and other altered volcanic rocks; granite, granodiorite, and similar intrusive igneous rocks.	Little information available. Probably will yield only small supplies at most places. Fractured crystalline rocks, coarser-grained sedimentary strata may yield moderate supplies at a few places.	Little data available. Probably generally low in dissolved solids; soft to moderately hard. Calcareous rocks will yield water higher in dissolved solids and hardness.

Water in Storage

A rough estimate of the quantity of water stored, in a specified depth interval below the water table in each aquifer unit, is given in table 97 as shown below.

Table 97 - Storage, Recharge, and Discharge of Ground Water in Aquifer Units, Subregion 2

Aquifer Unit	Area		Storage			Annual Natural Recharge and Discharge	
	Sq.Mi.	Acres (1,000)	Specific Yield (percent)	Depth Used (ft)	Water (1,000 ac-ft)	Inches Over Area	(1,000 ac-ft)
Qg	3,600	2,300	20	50	23,000	10	1,900
Tcr	7,830	5,000	1	100	5,000	2	830
Tv	540	345	2	50	340	6	170
TKc	400	250	2	50	250	6	125
pT	9,630	6,150	2	50	6,150	6	3,000
TOTAL (rounded)	22,000	14,000			35,000		6,000

Specific yields of alluvial materials range from a few to perhaps 30 percent. The alluvial and glacial deposits are predominantly sand and gravel, so a specific yield of 20 percent was used for this unit.

The basalt-aquifer unit is chiefly in the broad, gently rolling plateau south of the Columbia River. Because the region is arid to semiarid--8 to 15 inches of rainfall--recharge is small, the water table generally is at a considerable depth, and the zone of saturation is in unweathered rock. A specific yield of 1 percent has been estimated for the unit.

The other three aquifer units occur in areas of higher precipitation north and northwest of the Columbia River where a moderately deep zone of weathering has developed on the underlying rock. Because of moderate amounts of rainfall, 15 to 50 inches, and the low porosity and permeability of the underlying unweathered rock, the water table is at shallow depths in the weathered mantle. The specific yield probably ranges from less than 1 to more than 10 percent and a value of 2 percent was assumed for the upper 50 feet.

A saturated thickness of 100 feet was used to estimate storage in the basalt of the Columbia River group (Tcr). A thickness of 50 feet was used for all other aquifer units. According to table 97, about 35 million acre-feet of ground water is stored in the specified depth intervals, with 23 million acre-feet in the alluvial-aquifer unit and 5 million acre-feet in the basalt. Where alluvium overlies the basalt, the storage shown is that of the alluvium, so withdrawals from the basalt in those areas would, in some places, deplete the storage in the alluvium. Such depletion

would lower the water table at a rate of 5 feet for each foot of water removed from storage, rather than at the rate for the basalt which is a lowering of 100 feet for every foot of water removed from storage.

Natural Recharge and Discharge

Recharge to aquifer units north of the Columbia River is largely from direct precipitation during the winter and spring and from snowmelt during the spring. Recharge from irrigation and influent seepage of streams is significant in some areas in the Okanogan and similar valleys. South of the Columbia River in the area of the Columbia Basin project, recharge is chiefly from irrigation. Recharge from precipitation and surface and underground inflow is small in comparison. The water table has risen throughout the project area since irrigation began in 1952--more than 100 feet at some places. East of the Columbia Basin project area, recharge is largely from direct precipitation and snowmelt at most places. Seepage from streams may be an important source of recharge locally.

The seasonal fluctuation of water levels in observation wells in the alluvial and glacial-deposits aquifer unit ranges from less than a foot in arid areas to more than 10 feet in some areas of heavy precipitation or extensive irrigation. The seasonal fluctuations indicate a range in annual recharge of a few inches to more than 2 feet. An average annual rate of 10 inches was assumed for the aquifer unit for the subregion. Hydrographs of representative observation wells that tap the alluvial-aquifer unit and the basalt are shown in figure 182.

The basalt-aquifer unit crops out almost entirely in semi-arid areas where precipitation ranges from about 8 to 15 inches. Recharge to the basalt from precipitation and influent seepage is considered to be equivalent to an inch or less over the area. However, recharge from irrigation in the Columbia Basin project area probably is equivalent to several inches over the area. A figure of 2 inches over the area is assumed for average recharge to the basalt.

No records of water-level fluctuations are available for wells that tap other aquifer units. Discharge from those aquifers contributes throughout the year to the flow of streams and, during dry periods, may supply the entire discharge of some streams. Separation of the ground water-component of flow by means of duration curves indicates that the ground-water component probably ranges from 30 to 50 percent in many streams. Hydrographs in figure 183 show low-flow characteristics of selected streams. Because alluvial and glacial deposits are widespread in many basins in the subregion, it is not possible to say how much of the ground

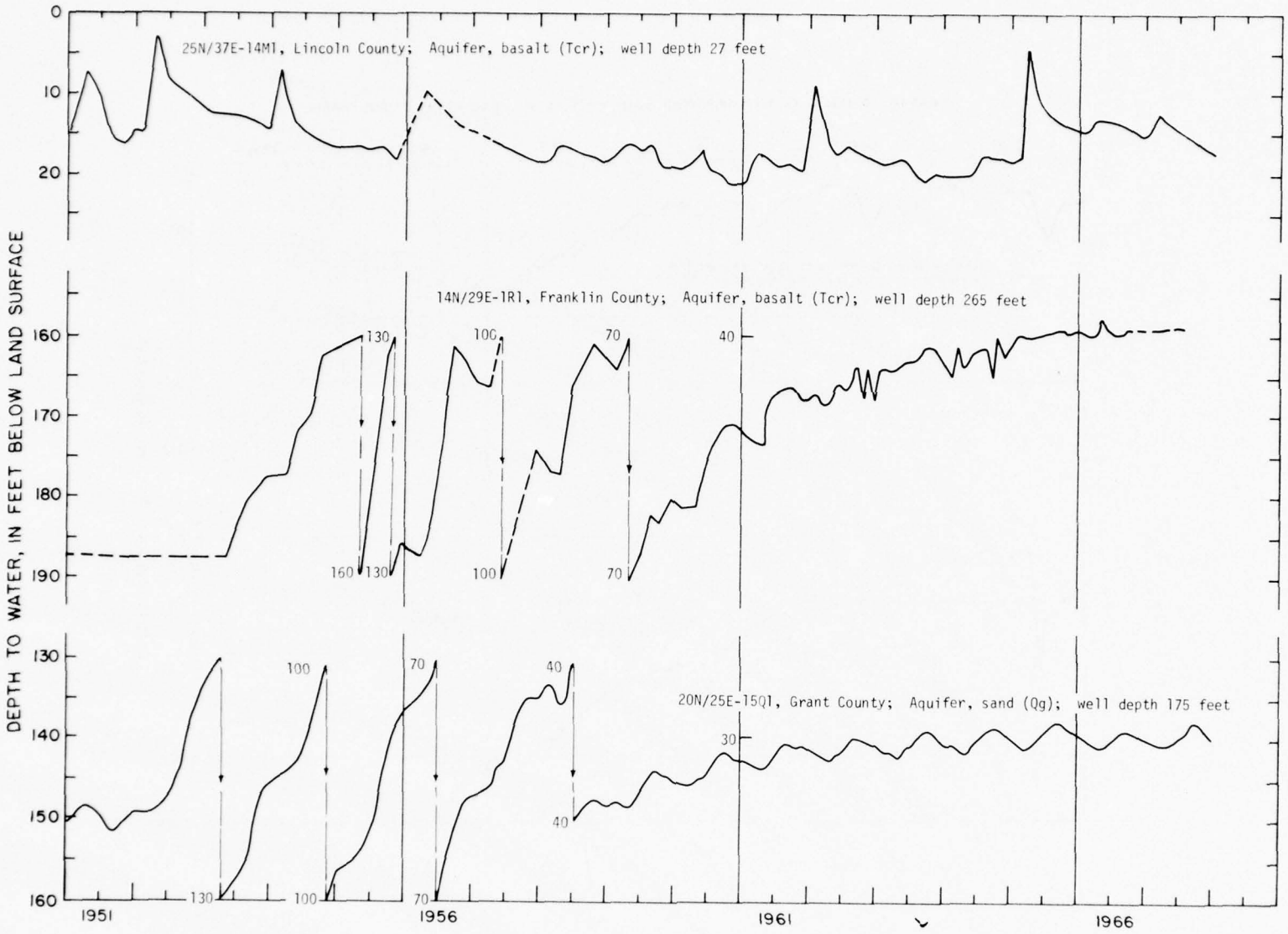


Figure 182 Hydrographs of selected wells in subregion 2

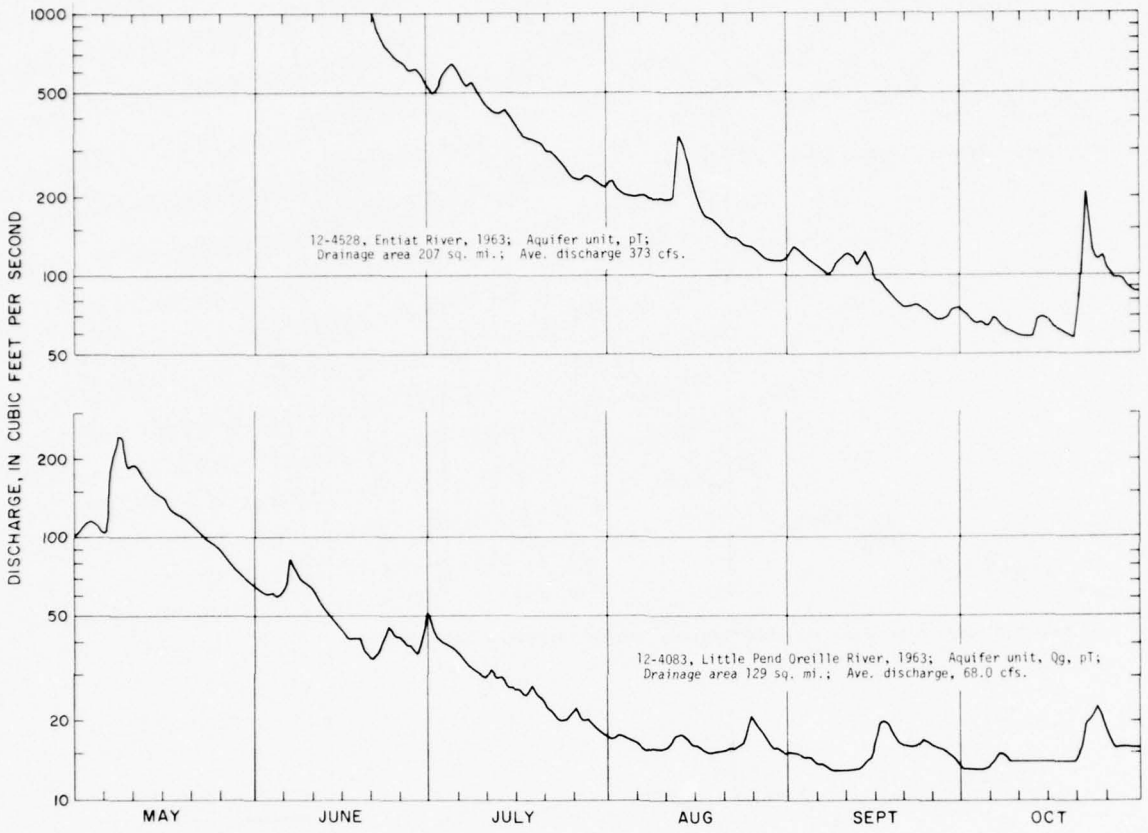


Figure 183. Hydrographs showing low-flow characteristics of selected streams

water flow is maintained by discharge from the other aquifer units. Values for recharge and discharge were based in part on comparison with other subregions. An estimate of the average annual natural recharge and discharge is given in table 97. According to the table, natural discharge from aquifer units in the subregion is about 6 million acre-feet a year of which about half is discharged from the pre-Tertiary aquifer unit. That quantity is almost equivalent to the volume of water stored in the upper 50 feet of saturation and suggests that most of the water stored is in the upper few feet of a much more porous zone, and that the storage is short-term with a rapid turnover. Hydraulic gradients are steep and the distance from point of recharge to point of discharge is short; water enters and leaves the aquifer in weeks or months. In contrast, hydraulic gradients in the alluvium and the basalt are low and the distance from point of recharge to point of discharge may be much farther so that depletion of water stored in those units is much slower.

Annual Ground-Water Withdrawal

Ground-water withdrawal (table 98), based on 1965 to 1967 data and projected to 1970, amounts to about 240,000 acre-feet a year. This is only a small percentage of the estimated annual natural recharge and discharge and, in fact, is much less than the probable error in estimates of natural recharge and discharge.

Chemical Quality of Water

The quality of the ground water generally is good. Dissolved solids rarely exceed 400 mg/l in water from the alluvial deposits and 500 mg/l in water from the basalt. Generally, the water is of the calcium magnesium bicarbonate type and is moderately to very hard, although the hardness rarely exceeds 250 mg/l. Boron and flouride commonly are low. Some deep wells in the basalt yield water in which sodium has replaced calcium through a natural softening process. Some wells yield very soft water with high sodium and flouride concentrations. Silica generally ranges from 30 to 60 mg/l. Temperatures range from about 50° to 65°F., but a few are less than 50°F. and some exceed 70°F. In wells in the Columbia River group, temperatures increase roughly 1°F. for each 50-foot increase in depth. (87, p. 59, figure 17)

Chemical analyses are given in most of the ground-water reports referenced previously. Many analyses and a discussion of water quality are contained in Washington State Water-Supply Bulletin 24. (175)

Table 98 - Estimated Ground-Water Withdrawal and Consumptive Use, Subregion 2, 1970

	(Ac-ft per year; all quantities in thousands)
Irrigation	
Acres Irrigated	60.0
Withdrawal	180.0
Consumptive use	90.0
Industrial[1]	
Withdrawal	15.0
Consumptive use[2]	.8
Public Supplies	
Persons served	95.0
Withdrawal	32.0
Consumptive use[3]	6.4
Rural-Domestic	
Persons served	105.0
Withdrawal[4]	11.8
Consumptive use[5]	5.9
Stock	
Withdrawals and consumptive use[6]	3.3
TOTAL WITHDRAWAL (rounded)	240.0
TOTAL CONSUMPTIVE USE (rounded)	110.0

1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

Present Use and Future Availability

Estimates of present use of ground water are based on data for 1965 and 1967, projected to 1970. Projection of public supply, domestic, and industrial use is on the basis of estimated population growth. Irrigation use was projected on the basis of past rates of increase, modified for special situations. Ground-water withdrawal and the amount used consumptively are given in table 98. In most areas where significant volumes of ground water are withdrawn, a large part of the water not used consumptively returns to the ground. However, part of the water withdrawn and not used consumptively may leave the subregion as surface flow so that the net withdrawal from the ground-water supply is somewhat greater than the consumptive use.

Ground-water withdrawal is about 240,000 acre-feet, consumptive use is about 110,000 acre-feet, and net ground-water withdrawal probably is about 0.15 million acre-feet annually. This is only about 5 percent of the annual natural discharge of about 2.7 million acre-feet from the two major aquifers and indicates a large potential for future development. However, neither recharge nor development is uniformly distributed over the area. In actuality, the areas with the greatest potential have the least present development and the areas with the smallest potential, because they are basically water-short areas, have now or are undergoing the greatest development. The alluvial and glacial deposits offer considerable potential for increased development where they are extensive. North of the Columbia River, natural recharge from precipitation and influent streamflow is large and probably would increase if withdrawals were increased substantially as some potential recharge is now rejected. In the Columbia Basin project, recharge from irrigation has raised the water table to near the surface in much of the area, and increased ground-water withdrawals from either or both major aquifers would alleviate waterlogging at some places. However, east of the project, natural recharge is small and large developments presumably would cause a decline in water levels.

Artificial Recharge

The only known artificial recharge is by the City of Okanogan, where average annual artificial recharge to the alluvium was reported to be 2,700 acre-feet. (125, p. 19) The glacial outwash and alluvial deposits (Qg) and the basalt (Tcr) both are suitable for recharging. Recharge incidental to irrigation is occurring in both aquifer units. It may be that the greatest opportunity for management of the ground-water supply lies in the planned conjunctive use of surface and ground water. Irrigation projects might be planned for surface diversion of part of the supply needed, the balance of the supply to be obtained from aquifers recharged by irrigation. This would not only reduce the amount of surface diversion required but would also reduce waterlogging problems.

Water Rights

In Subregion 2, consisting essentially of Water Resource Inventory Areas 36, 40 through 53, and 58 through 61 (figure 121), a total of 1,680 active ground-water right appropriation and declaration records, in permit and certificate stages, were on file with the State of Washington, Department of Water Resources, as of September 30, 1966. Prime rights in this area allow summer period consumptive withdrawals totaling 834,608 gpm (1,860 cfs). A total of 4,350 gpm has been appropriated under supplemental rights.

Prime water right quantities for the more important use categories and total actual ground-water right quantities are listed in table 99, according to Water Resource Inventory Areas as defined by the State of Washington, Department of Water Resources (Regional Summary). More detailed information about specific rights can be obtained from the Department of Water Resources.

Table 99 - Summary of Ground-Water Rights in Subregion 2, 1966

Basin No.[1]	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total[2]
		(Gallons per Minute)						
36	Esquatzel Coulee	5,350	90,724	38,772	4,144	-	6,256	103,288
40	Squilchuck-Alkali Cr	-	12,809	2,189	530	-	800	13,709
41	Lower Crab Creek	22,325	301,463	158,099	13,610	-	19,776	338,305
42	Soap-Banks Lake	6,490	45,011	18,333	50	950	5,807	53,773
43	Upper Crab-Wilson Cr	2,995	90,915	31,943	823	-	790	96,443
44	Douglas-Moses Coulee	1,950	49,761	13,779	500	-	830	54,380
45	Wenatchee	3,310	4,766	4,188	3,811	-	10	11,144
46	Entiat	1,300	1,068	398	-	800	382	3,168
47	Chelan	-	13,185	2,018	290	450	-	11,168
48	Methow	750	8,815	5,552	4,390	100	-	14,445
49	Okanogan	13,930	62,320	20,260	2,680	-	1,842	78,242
50	Foster Creek	450	19,062	11,627	525	-	-	21,277
51	Nespelem	-	1,075	-	-	-	-	1,075
52	Sanpoil	270	1,223	293	-	-	-	1,543
53	Grand Coulee-Hawk Cr	1,130	6,174	410	500	-	-	7,387
58	Ninemile-Sherman Cr	-	1,190	494	-	-	-	1,200
59	Colville	8,100	7,967	1,613	1,170	-	794	17,632
60	Kettle	-	4,160	167	-	-	-	4,232
61	Columbia-Deep Cr	-	122	2,120	-	-	-	2,197
TOTAL		68,350	721,810	312,255	33,023	2,300	37,287	834,608

1/ Water Resource Inventory Area number as shown in figure 121.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed and (2) water-right quantities that are common to two or more uses are listed under each applicable use category.

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

Streams that drain the hills and mountains, which are underlain chiefly by pre-Tertiary rocks, derive a part of their flow throughout the year from ground water. Generally, about one-third of their average annual discharge is ground water. Most of the streamflow during late summer and autumn is supplied by ground-water discharge. During late autumn and winter, ground-water effluent

furnishes a large part of the streamflow except for brief warm periods when flow is augmented by snowmelt or rainfall. In the spring and early summer, precipitation and snowmelt are much the larger component of streamflow. In larger valleys, such as the Columbia River, Okanogan, Kettle, and Sanpoil, some water goes into bank storage in the alluvial deposits during the spring and early summer runoff period. The deposits also are recharged by seepage from smaller streams entering the valleys. Discharge from the alluvial deposits helps maintain a high base flow later in the season.

The area south of the Columbia River is arid to semiarid and runoff is small to nonexistent. Water, flowing in intermittent and ephemeral streams, that does not evaporate seeps into the ground to recharge the alluvium or the basalt. Crab Creek, the largest stream in the area, with a drainage area of approximately 2,040 square miles above the Moses Lake gaging station, lost almost its entire flow before irrigation of the project began. Rocky Ford Creek, which rises in large springs a few miles west of Crab Creek, is entirely ground water fed and discharges into Moses Lake, a water-table lake. Prior to irrigation, considerable ground water discharged into the Moses Lake area because of a geologic structure that forms a barrier in the Columbia River group and the Ringold Formation. The barrier extends eastward approximately along Lind Coulee. Construction of O'Sullivan Dam on the geologic structure has raised the height of the barrier, and return flow from irrigation has greatly augmented the natural ground-water inflow to the Moses Lake area. Much of the southern part of the Columbia Basin project is irrigated with this water.

Discharge fom around the periphery of the area south of O'Sullivan Dam and Lind Coulee is into the Columbia and Snake Rivers which form the regional base level. The regional water table slopes generally west and southwest and most ground-water outflow from the area is into the Columbia River. Ground-water outflow from the 3,900 square mile area of the Columbia Basin project was estimated to be about 50,000 to 60,000 acre-feet a year prior to irrigation. (87, p. 54)



LOCATION MAP

SUBREGION 3

SUBREGION 3, YAKIMA

HYDROLOGIC FRAMEWORK

The Yakima Subregion, an area covering 6,062 square miles and representing about 2 percent of the total area of the Columbia-North Pacific Region, lies totally within the State of Washington. About 45 square miles are water and 6,017 are land.

The Cascade Range, rising on the western border of the Yakima Subregion to elevations of six to eight thousand feet, is flanked for many miles on the east by southeastward trending upwarped ridges. The Wenatchee Mountains, largest of the uplifts, comprise the northern border of the subregion. The Yakima River flows east and south through the Kittitas Valley from its ruggedly glaciated headwaters area. South of the valley, the river cuts through the flanking Manastash and Umtanum Ridges in a deep canyon. The river enters the middle valley above Yakima through a gap cut in Selah Ridge and leaves it through Union Gap in Ahtanum Ridge. Cleman and Cowiche Mountains, Tieton, Selah, Yakima, and Ahtanum Ridges border the middle valley. Rattlesnake Hills crossing eastern Yakima and northern Benton Counties and Horse Heaven Hills to the south are prominent features bordering the lower valley in its 80-mile reach from Union Gap to the Columbia River. The Yakima River joins the Columbia River at an elevation of 340 feet. The valley bottoms, the adjoining terraces, and the surrounding gentle slopes contain the subregion's agricultural land.

The larger glacial lakes fed from the mountain headwater area have been improved as storage reservoirs. The Yakima River is the outlet of Keechelus Lake, the westernmost of three such lakes. Ten miles downstream the Yakima River is joined by the Kachess River, a larger reservoir outlet; and 10 miles farther down its course the Yakima is joined by the Cle Elum River flowing from Cle Elum Lake, largest on the Yakima system. Teanaway River, Swauk Creek, and several smaller creeks contribute drainage from the Wenatchee Mountains. Taneum, Manastash, and Umtanum Creeks flow eastward between parallel ridges to join the Yakima from the west.

Joining the Yakima below its deep canyon section, the Naches River also taps a large and productive watershed east of the Cascade summit. Of its tributaries, Bumping River, flowing from the lake of that name, and Tieton River, outlet of Rimrock Lake (Tieton Dam), and Clear Lake reservoirs are the most important. Below Union Gap

the major tributaries of the Yakima are Ahtanum, Toppenish, and Satus Creeks entering from the west.

Geology of the subregion is relatively simple as the entire area is underlain by a great thickness of flows of dark gray to black basaltic lava. Fairly large exposures of rock may be found along the larger stream valleys and at higher elevations on the hills. A few layers of sediments are interbedded in the lava.

A period of deformation followed deposition of the lava, and anticlinal ridges and closed basins developed in the lava. Coarse, heavy sediments accumulated in the depressions. When a drainage system again developed and streams began to entrench their channels, the major streams cut deep, steep-walled canyons through the ridges. Much of the sediment was removed from the basins. Gravel deposits were left in many of the valleys.

During glacial time, the main river system was dammed, and the canyons and deeper basins were flooded. Thick deposits of silty to sandy sediments of glacial origin accumulated in the lake. After the dam broke and the streams were again free to cut their channels to former depths, much of the lake sediment was eroded. Remnants still remain throughout the area.

Since the disappearance of the lake, windblown materials have blanketed most of the area. Some of the material is of local origin, while other material has been transported from outside the subregion. Much of the soil, especially in the upland areas, has developed from the windblown mantle. This has left predominant soils of medium textured sandy loams and silty loams of considerable depth. The soils have developed under scant rainfall and have a high content of the mineral elements of fertility.

CLIMATE

The climate varies from desert conditions in the lower valley to a moist alpine type in the higher mountains. Some of the factors influencing the climate are topography, distance from the ocean, prevailing westerly winds, and the path of weather systems crossing the Pacific. To the east and north, the Rocky Mountains shield this area from winter season cold air masses moving southward across Canada. Occasionally, air from the interior of the continent spills over the Rockies or enters the inland basin through north-south valleys separating ranges in southern British Columbia.

To the west, the Cascades form a barrier to the easterly movement of moist air from over the ocean. Most of the air masses crossing the state have spent several days over the Pacific. The surface of the ocean is warmer in winter and cooler in summer than

the land. From June through August, the prevailing flow of air into the state is from the northwest and west. Warming of the air as it moves inland results in a dry season beginning in late spring and reaching a peak in midsummer. The prevailing flow of air into the state during late fall and winter is from the southwest and west. The maritime air is moist and near the surface temperature of the ocean. As it moves inland and rises along the western slope of the Cascades, the temperature decreases approximately 3°F. with each 1,000-foot increase in elevation. Orographic lifting of the air results in heavy precipitation along the western slope and near the crest. Air descending along the eastern slope becomes warmer and drier, increasing in temperature 4°F. or more with each 1,000-foot drop in elevation. The adiabatic cooling and warming as the air crosses the mountains results in warmer, drier air on the lee slope than at similar elevations on the windward slope.

Precipitation

There is a sharp reduction in precipitation as the elevation decreases in an easterly direction from the summit of the Cascade Range.

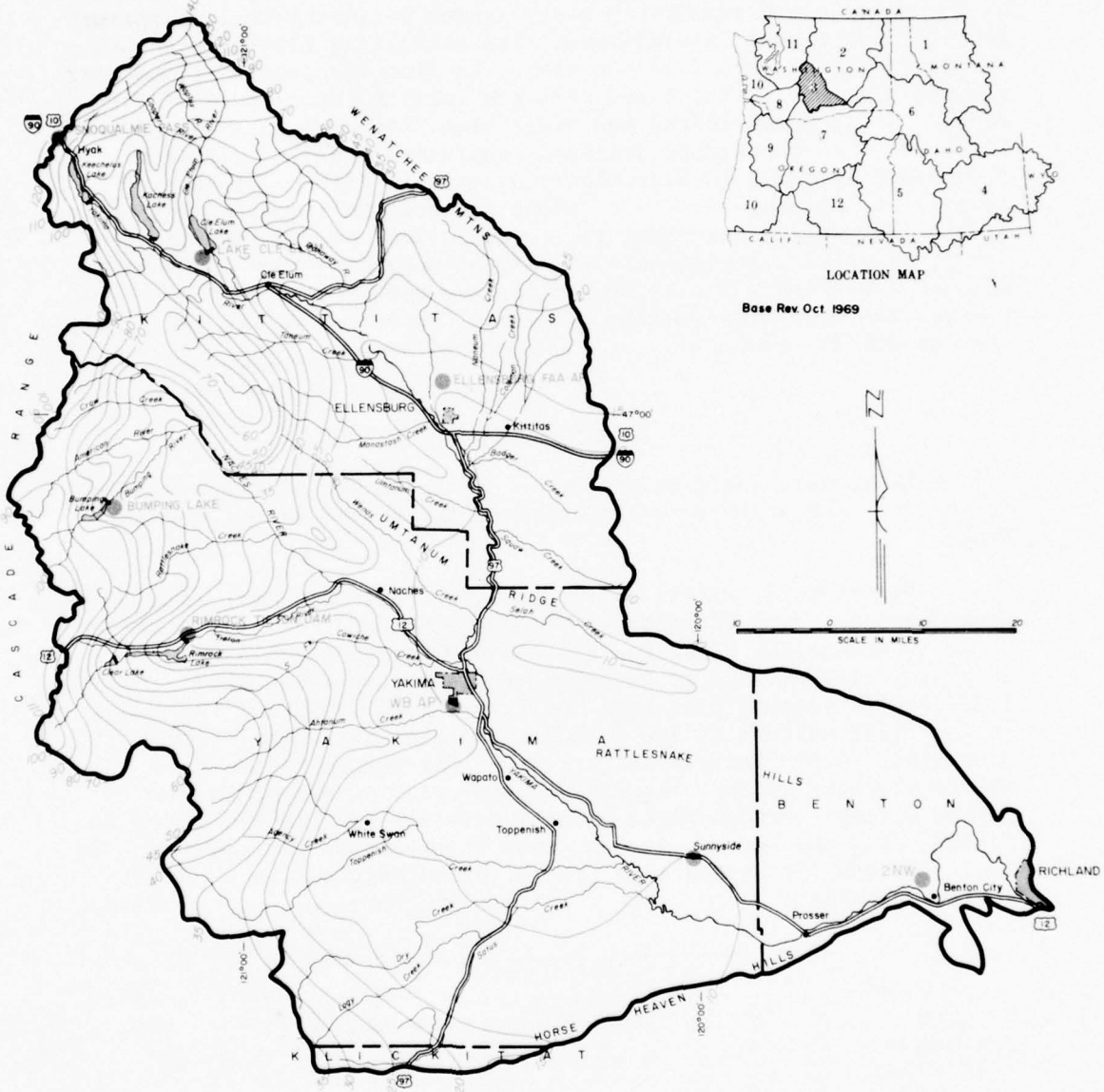
For example, within a distance of 20 miles, annual precipitation decreases from 92 inches at Stampede Pass (elevation 3,958 feet) to 22 inches at Cle Elum (elevation 1,920 feet). Within the next 20 miles, it decreases to 9 inches at Ellensburg (elevation 1,727 feet). Annual precipitation ranges from less than 10 inches in the lower valleys to 100 inches or more at the crest of the mountains. Approximately 50 percent of the precipitation falls in the four months October through January, and 75 percent in the period October through March. Total rainfall for the two driest months, July and August, is less than 5 percent of the annual. Table 100 and figure 184 show precipitation data and location of weather stations.

Table 100. Average Monthly and Annual Precipitation (inches), Yakima Subregion, 1931-1960

Station	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Benton City 2NW 1/	680	1.08	0.85	0.65	0.46	0.51	0.63	0.17	0.30	0.51	0.74	1.14	1.11	8.15
Bumping Lake	3440	7.85	6.03	4.82	2.29	1.77	1.59	0.53	0.64	1.52	4.28	7.25	9.25	47.82
Ellensburg FAA AP 2/	1727	1.26	0.90	0.76	0.49	0.59	0.83	0.13	0.23	0.44	0.66	1.20	1.37	8.86
Lake Cle Elum	2255	5.87	4.31	3.67	1.57	1.31	1.09	0.36	0.42	1.32	3.61	6.00	6.96	36.49
Rimrock-Tieton Dam	2730	4.21	2.89	2.41	1.16	0.96	1.02	0.34	0.50	0.76	2.36	4.21	5.30	26.12
Snoqualmie Pass 2/	3020	14.77	12.74	11.72	6.39	4.68	4.86	1.67	2.03	4.81	10.46	15.41	18.06	107.60
Sunnyside	747	0.89	0.66	0.48	0.42	0.51	0.84	0.18	0.21	0.35	0.72	0.76	0.88	6.90
Yakima AP 1/	1061	1.19	0.87	0.62	0.47	0.54	0.81	0.13	0.20	0.35	0.60	0.96	1.12	7.86

1/ Period may be longer or shorter than the 30-year normal.
2/ 1930-1959.

The drier areas receive measurable precipitation on 1 to 3 days each month in summer, 4 to 7 in spring and fall, 8 to 12 days in winter; and in the mountains, 5 to 10 days in summer, 12 to 18 in spring and fall, and 20 to 25 days in winter.



EXPLANATION

—10— Mean Annual Precipitation

Precipitation Station

NOTES

(1) ISOHYETAL ANALYSIS OF MEAN ANNUAL PRECIPITATION WAS MADE USING 1930-1957 DATA MODIFIED TO REFLECT BASIN PHYSIOGRAPHIC FEATURES, METEOROLOGIC FACTORS AND RUNOFF.

(2) STATIONS SHOWN ARE SELECTED STATIONS AND ARE NOT THE ONLY STATIONS USED IN PREPARING THIS MAP.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL PRECIPITATION IN INCHES

YAKIMA SUBREGION 3

1968

FIGURE 184

Figure 184 is an isohyetal map of mean annual precipitation prepared by the Weather Bureau River Forecast Center, Portland, Oregon, using climatological data (1930-57) and information derived from correlations with physiographic factors. Table 100 presents precipitation data for selected stations, but these are not the only stations used in preparing the isohyetal map.

Average snowfall in the lower valleys ranges from 15 to 30 inches annually, with accumulated depths of 5 to 20 inches. Snow can be expected by the first of December and to remain on the ground for periods ranging from a few days to six weeks between mid-December and the last of February. On the higher ridges, snow can be expected by the first of November and to remain on the ground from mid-November until June or later. Winter snowfall increases from approximately 75 inches at 2,000 feet to 400 inches or more at the crest of the Cascades. In the higher elevations, snow reaches depths of 10 to 15 feet almost every winter and 20 feet in the heavier snowfall seasons. The density of the snow pack increases from 25 percent water equivalent in early winter to 45 percent in March.

Temperature

During the warmest summer months, afternoon temperatures in the lower elevations range from 85° to 95°F. and minimums from 55° to 65°F. Maximum temperatures exceed 90° on 50 to 60 days and 100°F. on 5 to 10 days. The diurnal variation in relative humidity is from 25 percent in the afternoon to 70 percent near sunrise. On the higher slopes of the mountains, maximum temperatures range from 65° to 75°F. and minimum temperatures from 40° to 50°F. Maximum temperatures have reached 105° to 115°F. in the warmest valleys and 95° to 100°F. on the higher slopes. Table 101 and figure 184 show temperature data and location of weather stations.

Throughout the winter season, weather systems moving eastward from the Pacific and occasional outbreaks of cold air from the interior of Canada produce frequent changes in the weather. Maximum temperatures range from 25° to 35°F. and minimums from 15° to 25°F. Maximums are below freezing on 20 to 40 days and minimums below zero on 2 to 5 nights. In a few of the colder winters, below zero readings have been recorded on 10 to 20 nights. Minimum temperatures ranging from -20° to -25°F. have been recorded in most areas and -30°F. at a few reporting stations.

The growing season varies from approximately 140 days to 180 days. The average date of the last 32°F. temperature in the spring ranges from mid-April to mid-May, and the first in the fall is during the first half of October.

Table 101. Average and Extreme Temperatures (°F), Yakima Subregion

Station	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Benton City 2NW	Av. Max.	38.1	45.8	58.4	68.4	75.9	83.2	92.0	89.5	80.2	67.8	51.1	41.3	66.0
	Av. Min.	22.9	27.2	32.9	38.2	45.0	51.4	55.9	53.4	47.0	39.0	31.1	26.7	39.2
	Mean 1/	30.6	36.6	45.7	53.3	60.4	67.3	73.9	71.5	63.6	53.4	41.1	34.0	52.6
	Highest	67	72	85	98	103	106	114	106	103	92	81	76	114
	Lowest	-29	-23	8	15	24	34	40	36	22	11	-4	-30	-30
Bumping Lake	Av. Max.	33.0	37.9	42.5	50.0	58.4	64.2	74.5	74.7	67.3	56.3	42.1	34.1	52.9
	Av. Min.	13.9	16.1	20.3	26.5	32.6	38.3	42.4	41.5	35.9	30.3	23.9	18.9	28.4
	Mean	23.1	26.5	30.9	38.1	45.6	50.9	58.2	57.7	51.9	43.0	32.3	26.6	40.4
	Highest	55	60	73	80	89	94	101	97	94	85	66	61	101
	Lowest	-38	-35	-18	-3	13	22	27	23	17	-5	-12	-28	-38
Ellensburg 2/	Av. Max.	33.0	40.6	51.1	61.4	69.4	74.8	84.0	82.9	75.0	61.9	45.0	37.1	59.7
FAA AP	Av. Min.	16.2	21.4	28.5	34.8	42.5	48.6	53.8	52.4	44.8	35.9	26.9	22.5	35.7
	Mean	24.6	31.0	39.8	48.1	56.0	61.7	68.9	67.7	59.9	48.9	36.0	29.8	47.7
	Highest	60	62	79	90	95	100	107	100	97	87	71	59	107
	Lowest	-29	-27	-1	15	20	31	37	36	26	17	-6	-13	-29
Lake Cle Elum	Av. Max.	33.4	38.6	45.4	54.7	62.3	68.2	77.4	78.1	70.8	58.5	43.7	36.5	55.6
	Av. Min.	19.0	21.6	26.7	32.3	39.0	45.8	50.7	49.7	42.3	35.2	28.3	23.8	34.5
	Mean	26.0	29.9	35.7	43.6	51.2	57.1	64.3	63.4	56.9	46.8	35.5	30.3	45.1
	Highest	56	58	73	88	92	97	105	100	97	88	75	64	105
	Lowest	-26	-28	-11	9	18	29	32	31	21	12	-8	-13	-28
Rimrock-Tieton	Av. Max.	34.1	39.4	46.0	55.2	63.4	69.5	79.5	78.1	70.5	58.4	43.9	36.6	56.2
Dam	Av. Min.	17.4	20.7	25.8	31.6	37.3	43.1	47.2	45.7	40.7	33.9	26.8	22.0	32.7
	Mean	25.6	29.8	35.3	43.4	50.5	56.1	63.0	61.7	56.1	46.3	35.1	29.8	44.4
	Highest	59	64	76	86	92	96	103	98	95	86	68	61	103
	Lowest	-25	-22	-8	4	20	26	31	30	19	9	-6	-2	-25
Snoqualmie Pass 2/	Av. Max.	32.1	35.7	42.6	50.7	57.7	62.3	69.9	68.6	63.6	53.2	39.6	33.3	50.8
	Av. Min.	20.4	22.1	26.1	30.5	34.7	40.0	45.7	45.8	41.7	35.0	27.6	24.4	32.8
	Mean	26.3	28.9	34.4	40.6	46.2	51.2	57.8	57.2	52.7	44.1	33.6	28.9	41.8
	Highest	51	76	69	81	84	92	101	95	101	88	60	53	101
	Lowest	-17	-15	0	7	16	27	31	34	26	13	-6	-6	-17
Sunnyside	Av. Max.	38.0	46.3	57.9	67.7	75.6	82.2	90.2	88.4	79.1	66.9	50.1	40.3	65.2
	Av. Min.	21.6	26.1	30.9	36.8	44.1	49.9	53.6	51.3	44.9	36.6	29.7	25.4	37.6
	Mean	30.2	36.0	44.2	52.6	60.5	66.2	72.1	69.7	63.2	52.6	39.7	33.8	51.7
	Highest	70	71	82	96	101	106	112	108	99	88	76	69	112
	Lowest	-26	-19	7	16	24	32	39	36	18	14	-23	-30	-30
Yakima 1/	Av. Max.	35.5	44.7	53.9	64.7	73.9	79.5	88.3	85.5	78.4	63.9	48.3	39.7	63.0
WB AP	Av. Min.	16.4	23.5	28.4	34.3	43.1	49.2	52.6	50.4	43.7	34.9	27.0	23.2	35.6
	Mean	27.5	34.0	42.0	50.5	58.5	64.4	71.0	68.6	61.3	50.5	37.4	31.5	49.8
	Highest	64	69	80	88	98	103	105	102	100	85	70	62	105
	Lowest	-21	-25	-1	21	25	33	35	35	29	17	-3	-2	-25

1/ Period may be longer or shorter than the 30 year normal 1930-1959.
2/ Temperature extremes are for period of record through 1960.

Wind

The prevailing direction of the wind is from the west and northwest; however, the highest velocities are from the southwest. The average velocity ranges from approximately 6 miles per hour (mph) in winter to 9 mph in summer. The diurnal variation in wind is small in winter; however, in summer there is a noticeable increase in the velocity from the west and northwest in late afternoon. Extreme winds at 30 feet above the ground can be expected to reach 50 mph at least once in 2 years, 60 to 75 mph once in 50 years, and 80 mph or higher once in 100 years.

Evaporation

Annual evaporation from a class A pan is estimated at 50 to 60 inches in the lower valleys and 30 to 40 inches on the higher slopes. Monthly amounts are from 2 to 5 inches in spring and fall and 6 to 9 inches in summer. Annual loss by evaporation from lakes and reservoirs is estimated at 25 inches in the mountains and 40 inches in the lower valleys.

Evapotranspiration

The potential evapotranspiration is 25 to 30 inches in the lower valleys and 18 to 22 inches on the higher slopes. Assuming that soils have a water storage capacity of 6 inches, computations have been made of the actual evapotranspiration which occurs with normal precipitation and temperatures. Estimated annual amounts are 6 to 8 inches in valleys and 12 to 15 inches in the mountains. Potential evapotranspiration exceeds actual evapotranspiration by approximately 6 inches in the mountains and 20 inches in the valleys.

Storms

During the warm season, precipitation frequently occurs as showers and is associated with thunderstorm activity. Occasionally rather intense thunderstorms develop over the mountains and heavy showers and hail are reported. Flash floods have occurred at the mouth of canyons. A few of the thunderstorms drift across the valleys; however, most follow the higher ridges in an easterly direction from the summit of the Cascades.

Sunshine

During the colder months, the loss of heat by radiation at night and moist air crossing the Cascades result in considerable

fog and cloudiness. Heavy fog is reported on 4 to 8 days each month from November through February. The number of clear or only partly cloudy days each month is from 5 to 8 in winter, 10 to 20 in spring and fall, and 20 to 28 in summer. The percent of possible sunshine received each month is from 15 percent to 25 percent in winter, 40 percent to 60 percent in spring and fall, and 75 percent to 85 percent in summer.

SURFACE WATER

The principal streams draining the east slope of the Cascade Range in the northern portion of the subregion are the Yakima, Kachess, and Cle Elum Rivers. Farther south is the Naches River, whose main tributaries, Bumping and Tieton Rivers, also head in the east slope of the Cascades. Issuing from the foothills of the Cascade Range south of the Naches River are the North and South Forks of Ahtanum Creek, Toppenish, and Satus Creeks.

Quantity

The average annual discharge from the subregion is about 3,240 cfs or 0.54 cfs per square mile, one of the lower rates in the region.

Present Utilization

Average annual diversions within this subregion total about 2,400,000 acre-feet for irrigation of approximately 500,000 acres. Diversions for other uses such as industrial, municipal, etc. are small in comparison. Diversions are comprised of natural flow, storage releases, and return flows. There are also some diversions made for hydroelectric power generation.

Table 102 - Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More, Subregion 3

Name	Stream	Total Storage (acre-feet)	Active Storage (acre-feet)	Surface Area (acres)	Use 1/
Bumping Lake	Bumping R.	33,700	33,700	1,310	IR
Cle Elum Lake	Cle Elum R.	436,900	436,900	4,800	IR
Clear Creek Lake	N.F. Tieton R.	5,300	5,300	265	IR
Kachess Lake	Kachess R.	239,000	239,000	4,525	IR
Keechelus Lake	Yakima R.	157,800	157,800	2,526	IR
Rimrock Lake	Tieton R.	198,000	198,000	2,528	IR

1/ R - recreation, I - irrigation.

Stream Management

Competition for water among the various users necessitates efficient stream management. Storage and releases, diversions, conservation, legal constraints, etc., all are a part of the water management system.

Impoundments Reservoirs in the subregion having a total capacity of 5,000 acre-feet or more are listed in table 102. The uses listed are those which are now considered prime functions of the reservoirs and do not necessarily represent the specific considerations in the planning of the reservoirs or the only uses of the reservoirs. These reservoirs are also used for flood control on an incidental basis.

Diversions The largest diversions are for irrigation. There are also diversions for generation of hydroelectric power. Power diversions are nonconsumptive and the water is generally returned to the stream within a short distance of the diversions, although in one instance the distance is about 12 miles.

Channel Modification Channel modification generally has been in the form of either bank protection or levee construction as flood control measures. Dredging is sometimes used to increase channel capacity for flood control. However, its effects are limited and confined to reaches of the river where it will not interfere with irrigation intake works which conform to present stream conditions.

Forecasting Forecasting of runoff is used primarily to assure optimum control and use of water for irrigation. Forecasting for flood control is also practiced to permit multiple use of storage consistent with regulation of water for irrigation.

Constraints There are no interstate compacts or international treaties that are concerned with runoff in the Yakima Subregion.

Surplus Water There is almost complete utilization of water during the irrigation season. The only surplus water would be uncontrolled flows during the winter and spring. With the present level of irrigation development, large shortages in certain areas can occur. Additional storage facilities would reduce these irrigation shortages and would also reduce the winter and spring surplus discharge.

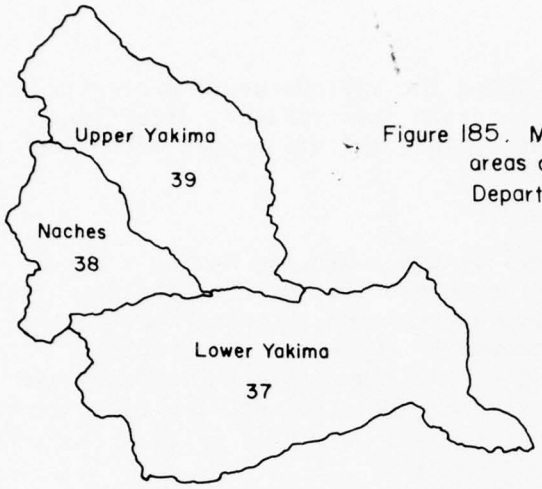


Figure 185. Map showing water resource inventory areas defined by the State of Washington Department of Water Resources.

Water Rights

In the Yakima Subregion, consisting essentially of Water Resource Inventory Areas 37 through 39 (figure 185), a total of 217 active surface water right appropriation records in permit and certificate stages were on file with the State of Washington Department of Water Resources on April 30, 1967. Prime appropriative rights in this area allow summer period diversions totaling 5,654 cfs with consumptive diversions amounting to 5,462 cfs, partially consumptive diversions 175 cfs, and nonconsumptive diversions 17 cfs. Under supplemental rights a total of 33 cfs has been appropriated.

A total of 537 adjudicated rights has been decreed in this subregion. These allow prime right diversions totaling 598 cfs, all of which are classified as being consumptive to the resource. Supplemental adjudicated rights have been granted for a total of 4 cfs.

Reservoir storage rights obtained under the appropriative procedure allow a total annual retention of 1,077,886 acre-feet in the Yakima Subregion.

Prime water right quantities for the more important use categories and total actual surface water right quantities are listed in table 103 according to Water Resource Inventory Areas as defined by the State of Washington Department of Water Resources. (Regional Summary) More detailed information about specific rights can be obtained from the Department of Water Resources.

Table 103 - Surface Water Rights, Yakima Subregion, 1967

Basin No.[1]	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total[2]	Reservoir Storage Rights
		(Cubic Feet per Second)							(Acre-Feet)
37	Lower Yakima	115.20	637.88	1608.19[3]	105.55	23.30	0.03	1895.20[4]	175
38	Naches	30.00	50.30	52.37	50.00	27.81	0.02	121.97	242,600 [9]
39	Upper Yakima	1.00	2526.48[7]	3542.08[7]	2.00	7.00	0.96	3636.71[7]	835,111[10]
Appropriative Totals		146.20	3214.66	5202.64	157.55	58.11	1.01	5653.88	1,077,886
37	Lower Yakima	-	204.19[5]	204.19[5]	-	-	203.81[5]	204.19[5]	-
38	Naches	-	44.25[6]	44.25[6]	-	-	44.25[6]	44.25[6]	-
39	Upper Yakima	-	349.68[8]	157.58[8]	-	-	157.58[8]	349.48[8]	-
Adjudicated Totals		-	598.12	406.02	-	-	405.64	597.92	-
Combined Totals (Approp. & Adjud.)		146.20	3812.78	5608.66	157.55	58.11	406.65	6251.80	1,077,886

1/ Water Resource Inventory Area number as shown on figure 185.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed and (2) water right quantities that are common to two or more uses are listed under each applicable use category.
3/ Includes 1000.00 cfs common with power generation use and 600.00 cfs common with irrigation use.
4/ Includes 1013.00 cfs for power generation use.
5/ Nearly all of the quantities for stock use and individual and community domestic supply are common with irrigation use.
6/ The quantities for irrigation, individual and community domestic supply and stock use are all common.
7/ A total of 2443.00 cfs is common among hydroelectric power generation, irrigation, and individual and community domestic uses.
8/ A total of 157.58 cfs is common among irrigation, individual and community domestic supply and stock uses.
9/ Includes 5800 acre-feet in Clear Lake, 202,500 acre-feet in Rimrock Lake, and 34,000 acre-feet in Bumping Lake.
10/ Includes 437,000 acre-feet in Cle Elum Lake, 157,800 acre-feet in Keechelus Lake, and 270,000 acre-feet in Kachess Lake.

Discharge

Within this subregion, two streams, Cle Elum River near Roslyn and Bumping River near Nile, which are not affected by irrigation depletion, show base period (30-year) mean discharges equal to about 98 percent of their long-term (62- and 56-year) means. Weather records show that precipitation at Lake Cle Elum and Bumping Lake during the base period was about 100 and 102 percent of the long-term (52- and 49-year in 1960) means. Thus, the selected base period provides representative data for statistical analysis.

Measurement Facilities Summarized on table 104 are pertinent data for streamflow gages. Figure 186 shows the location of the selected sites with Geological Survey identification numbers.

Table 104. Streamflow Summary for Selected Sites, Subregion 3

Stream	Station	Station Number	Gage Datum	Drainage Area (sq mi)	Period of Record	Annual Flow 1/ (cfs) Mean	Max.	Min.	Momentary Flow 2/ (cfs) Max.	Min.
Yakima River	Martin	4745	2,422.40	54.7	03-65	327	563	169	7,370	0
Kachess River	Easton	4760	2,188.10	63.6	03-65	286	526	134	2,530	0
Cle Elum River	Roslyn	4790	2,102.10	203	03-65	911	1,630	537	18,700	0
Yakima River	Cle Elum	4795	1,900	495	06-65	1,575	3,092	879	25,600	46
Yakima River	Umtanum	4845	1,300.00	1,594	06-65	2,325	4,374	1,290	41,000	138
Bumping River	Nile	4880	3,367.10	70.7	09-65 3/	288	538	154	5,180	0
American River	Nile	4885	2,700.00	78.9	39-65 3/	235	420	150	2,600	20
Tieton River	Tieton Dam	4915	2,680.99	187	25-65 3/	495	887	278	8,450	0
Naches River	Naches	4940	1,549.67	941	08-65 3/	1,478	2,769	786	32,200	1
N. F. Ahtanum Creek	Tampico	5005	2,450	68.9	07-65	65	119	29	823	4
S. F. Ahtanum Creek	Conrad Ranch	5010	2,400	24.8	15-65	19	34	7	424	2
Yakima River	Parker	5050	885.89	3,668	08-65	1,894	5,113	356	65,000	4
Yakima River	Kiona	5105	454.41	5,615	33-65 3/	3,240	6,843	1,540	67,000	105

1/ Regulated values for base period (1929-1958) 1970 conditions.
2/ Observed values for period of record.
3/ Denotes other short periods of record.



LOCATION MAP

Base Rev. Oct. 1969

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES
YAKIMA SUBREGION 3

1968

FIGURE 186

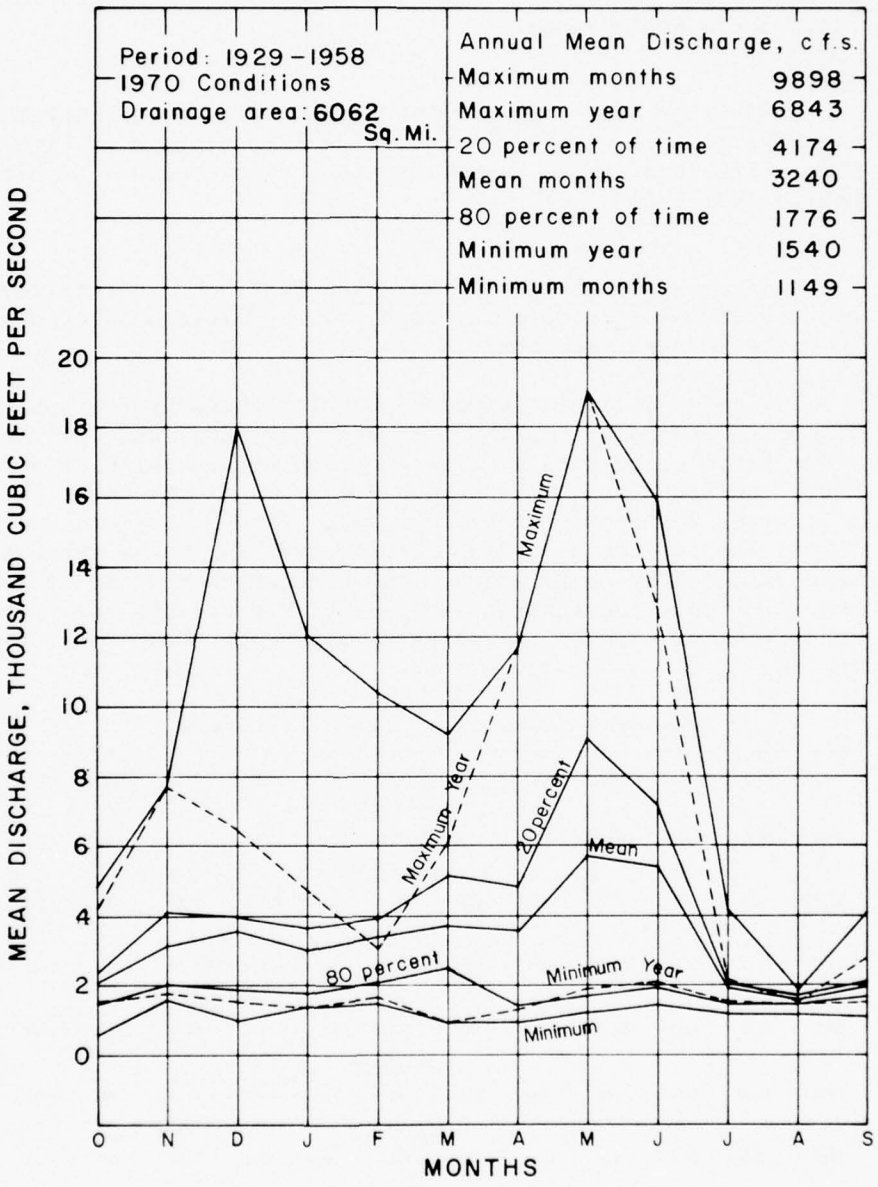


Figure 187. Monthly discharge, Yakima Subregion

The first two digits of the identification number, part number (12), have been omitted because Subregion 3 lies entirely within the area designated as Part 12, the Washington coast and the Columbia River Basin above Snake River.

Average Discharge for Subregion 3 The flow generated within the subregion is shown in table 105 and is plotted as figure 187. Figure 186 is a map of isopleths showing mean annual runoff for the period 1931-1960.

Average Discharge for Selected Stations In this section of the report detailed data for each of the selected sites described in table 104 are presented.

The monthly discharges upon which these hydrographs are based are generally taken from a computer study made of the Yakima River Basin water supply. The American River near Nile and the North and South Forks of Ahtanum Creek are exceptions. The monthly discharges for these streams are taken from Geological Survey Water Supply Papers 1316 and 1736. The records for these three stations were extended by correlation. The discharges for the stations are shown in table 106 through table 118. Hydrographs for several conditions of flow of the selected sites are shown on figures 188 to 200.

Table 105. Modified Mean Discharge, in CFS, in Yakima Subregion

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
						MAXIMUM						
4833	7670	17995	12038	10383	9209	11718	19033	15877	4143	1821	4062	9898
						MAXIMUM YEAR						
4255	7670	6443	4718	3013	6076	11718	19033	12796	2124	1537	2736	6843
						20 PERCENT						
2349	4118	3975	3614	3950	5146	4832	9072	7156	2040	1729	2105	4174
						MEAN						
2051	3134	3533	2966	3344	3685	3552	5712	5409	1911	1584	1994	3240
						80 PERCENT						
1492	2023	1885	1746	2063	2452	1380	1674	1950	1517	1486	1648	1776
						MINIMUM YEAR						
1548	1730	1536	1339	1637	925	1268	1905	2042	1534	1487	1525	1540
						MINIMUM						
572	1573	958	1339	1488	925	930	1196	1426	1181	1144	1057	1149

20 percent and 80 percent represents the runoff available 20 percent and 80 percent of the time.

Frequency curves of mean discharge are shown on figures 201 to 213. These curves present the highest and lowest average flow for periods of 1, 3, 6, and 12 consecutive months. The mean annual flow is also indicated.

Duration curves for monthly and annual flows are presented in figures 214 to 226. The daily curves are shown only when data are available from Geological Survey daily summaries and are for the entire period of record. The discharge for the maximum day is listed on the graph because of space limitations.

Frequency curves of annual peak flows are shown in figures 227 to 239. These curves were computed using the standard method of the Corps of Engineers (Beard, 1962). The entire period of record is used in defining these curves.

Dependable yield of the river basins is given in tables 119 to 131. These tables show the lowest mean flows for from 1 to 10 consecutive years out of the 30-year base period. The relationship of these means to the 30-year mean is also given. The minimum year for all streams ranges between 64 and 18 percent and averages 50 percent of the mean. These tables show that the use of the mean annual discharge to determine the total amount of water in a stream is not realistic, even with carryover storage. The use of the minimum year or some point on the duration curve, such as the 90 percent point, presents a more practical approach to estimating the total amount of water that could be made available.

Variations in Discharge Long-term variations in discharge and precipitation are presented in figure 240 and figure 241 (pages 321 and 322). The means for the base period and for the entire period of record are shown. The means used for discharge are from Water Supply Papers instead of the computer study because the data from the computer study are for the base period only.

The mean precipitation of 46.37 inches at Bumping Lake and 35.77 inches at Lake Cle Elum for the 30-year base period are about 102 and 100 percent of their long-term (49- and 52-year in 1960) mean. This indicates that the selected base period is representative of the long-term period. Also, the graphs show the maximum and minimum of record occurred during the base period which again gives more meaning to the base period record. The base period discharge for both is about 98 percent of the long-term mean indicating that the data used in the analyses represent average conditions. The ratios of base period discharge to long-term mean at about one-half of the other sites are similar while the others are affected by irrigation depletions.

The graphs also present 5-year moving averages for precipitation and discharge. These averages show the relationship between precipitation and discharge. The data presented indicate no long-term trend, either declining or increasing, or long-term rhythmic cycle of precipitation or discharge.

The duration curves for selected sites as seen in figures 214 to 226 show the range in annual flows. The range in annual flows during the 30-year base period varies considerably at some stations. The maximum year varies between 3 and 12 times the minimum year.

Seasonal variations in runoff are clearly shown in the hydrographs of figures 188 to 200. These hydrographs indicate that two peaks occur, one during the winter and the other in the spring. The winter flood is an occasional occurrence, as shown by the mean hydrograph, but may have a peak as great as the spring snowmelt flood. At several of the stations, the winter peak is larger than the spring peak for the maximum year of record. Since most of the gages are below storage reservoirs, the winter floods with less volume and more storage available are more highly regulated than the normal large volume spring and summer snowmelt floods.

Streamflow Travel Time The data available on streamflow travel time are limited to the travel time of releases from the various reservoirs to Sunnyside Diversion Dam, located one-tenth of a mile above the station Yakima River near Parker. Data on travel time of releases from Keechelus Lake, Kachess Lake, and Cle Elum Lake to intermediate stations between the reservoirs and Sunnyside Diversion Dam are not available. There is one station, Naches River below Tieton River near Naches, and an additional location, Tieton Canal headworks, at which travel time of releases from Rimrock Lake is available. Travel time of releases from Bumping Lake is also available at the station on the Naches River. The streamflow travel time is presented on figure 242.

River Profiles River profiles for selected streams are shown in figures 243 and 244. The profiles are based on River Mile Indexes published by the Columbia Basin Inter-Agency Committee.

The Yakima River flows for a distance of about 175 miles from the outlet of Keechelus Lake to the Columbia River. The elevation range is from 2,450 feet to 340 feet, a total of about 2,100 feet. With a stream gradient of this magnitude and with fairly consistent medium flows, either before irrigation diversion from the stream or after large return flows have entered the river, some hydroelectric power production is possible. The same situation exists, to some extent, with the Naches River, which begins at the confluence of Bumping River with Little Naches River, and drops about 1,500 feet in 45 miles.

(Narrative continued on page 324)

Table 106. Modified Mean Discharges, in CFS, Yakima River near Martin, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							0	686	343	694	818	452	
1929	197	0	0	0	0	0	261	203	497	886	837	541	285
1930	167	0	0	0	0	0	0	411	980	611	377	215	230
1931	138	0	0	0	0	0	124	171	812	1065	371	212	240
1932	122	0	0	0	0	0	0	441	891	728	828	539	296
1933	207	908	112	302	0	0	0	151	1092	602	681	1252	442
1934	641	397	959	485	22	574	250	364	531	774	750	447	516
1935	47	81	0	511	0	0	64	356	701	655	758	524	308
1936	184	0	0	0	0	0	0	898	748	719	805	497	321
1937	158	0	0	0	0	0	0	63	928	634	750	479	251
1938	215	523	42	115	0	0	0	554	445	694	798	516	325
1939	128	0	0	0	0	0	114	691	566	807	844	529	307
1940	190	0	0	0	0	0	0	455	661	963	883	454	300
1941	94	0	0	0	0	0	0	625	449	302	302	489	188
1942	88	0	0	0	0	0	0	286	558	997	642	350	243
1943	148	0	0	0	0	0	0	91	850	499	750	854	266
1944	122	17	62	0	0	0	182	465	674	917	844	294	298
1945	179	0	0	0	0	0	108	93	454	1109	993	613	296
1946	215	0	0	0	0	0	0	182	1002	652	795	716	297
1947	294	59	283	259	23	211	146	737	432	702	720	472	362
1948	415	437	0	0	0	0	0	587	1213	628	672	785	395
1949	234	129	0	0	0	0	0	954	808	668	699	790	357
1950	363	492	23	109	0	55	0	520	1321	624	642	1180	444
1951	407	422	223	158	302	0	0	852	634	624	740	501	407
1952	328	134	0	0	0	0	0	447	471	724	735	588	286
1953	124	0	0	145	149	0	25	522	612	517	657	881	303
1954	164	200	289	153	0	0	0	593	975	652	649	1284	413
1955	215	249	0	0	0	0	175	0	1018	641	758	1079	345
1956	522	481	73	41	0	0	0	1018	1059	551	680	471	408
1957	979	178	574	21	0	0	0	667	376	808	766	548	410
1958	55	0	0	0	0	0	0	693	471	732	787	472	268
Mean	244	158	88	77	17	28	48	470	741	715	718	618	327

Table 107. Modified Mean Discharges, in CFS, Kachess River near Easton, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							0	769	361	862	1088	694	
1929	72	0	0	0	0	0	274	121	395	751	940	800	279
1930	213	0	0	0	0	0	0	367	316	424	655	523	208
1931	73	0	0	0	0	0	116	158	397	541	675	524	207
1932	75	0	0	0	0	0	0	0	0	719	943	716	204
1933	128	0	0	0	9	0	0	380	973	462	870	590	284
1934	423	341	1020	502	272	538	311	397	592	1037	1130	771	611
1935	33	0	0	0	0	0	72	0	371	764	1015	771	252
1936	210	0	0	0	0	0	0	46	674	907	1132	771	312
1937	200	0	0	0	0	0	0	21	0	689	989	671	214
1938	207	0	0	0	0	0	0	132	450	837	1096	813	295
1939	141	0	0	0	0	0	24	0	471	876	1072	790	281
1940	193	0	0	0	0	0	0	70	430	824	1028	818	280
1941	78	0	0	0	0	0	0	428	418	250	268	422	155
1942	55	0	0	0	0	0	0	249	363	421	633	597	193
1943	203	0	0	0	0	0	0	0	0	392	785	603	165
1944	89	0	0	0	0	0	176	351	464	930	1093	439	295
1945	257	0	0	0	0	0	106	78	361	515	807	788	243
1946	119	0	0	0	0	0	0	0	0	566	883	593	180
1947	20	0	0	0	56	167	77	631	334	846	1033	697	322
1948	0	0	0	0	0	0	0	385	1042	704	863	708	308
1949	0	0	0	0	0	0	0	857	716	689	902	703	322
1950	0	0	44	151	108	98	0	608	1134	486	798	686	343
1951	88	355	304	218	506	0	0	880	536	735	992	778	449
1952	0	0	0	0	0	0	0	0	274	823	1005	887	249
1953	132	0	0	0	0	0	25	0	281	533	893	770	220
1954	0	0	0	98	144	0	0	738	852	554	772	622	312
1955	104	178	0	0	178	0	180	75	1015	481	937	716	322
1956	8	496	167	102	63	0	32	1268	861	398	872	647	410
1957	0	81	587	78	65	0	0	805	338	984	1034	854	402
1958	88	0	0	0	0	0	0	0	316	953	1068	627	254
Mean	107	48	71	38	46	27	46	302	479	667	907	692	286

Table 108. Modified Mean Discharges, in CFS, Cle Elum River near Roslyn, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							220	3371	1674	2239	2367	1306	
1929	220	25	25	25	25	25	748	611	1361	2366	2512	1425	781
1930	429	25	25	25	25	25	25	1325	1845	1689	1480	450	614
1931	233	25	25	25	25	25	341	584	1966	2377	1423	486	628
1932	517	25	25	25	25	25	25	1161	2603	2145	2374	1494	870
1933	356	417	364	223	25	25	25	1997	3442	2091	2161	2066	1099
1934	1610	1136	1938	672	418	922	2338	2055	2148	2428	2420	1284	1614
1935	93	25	25	25	25	25	234	2041	2376	2135	2320	1523	904
1936	433	25	25	25	25	25	25	2140	2316	2239	2338	1345	913
1937	411	25	25	25	25	25	25	94	2131	2049	2228	1301	697
1938	509	25	25	25	25	25	25	2628	2250	2250	2319	1373	957
1939	332	25	25	25	25	25	99	1062	1733	2488	2525	1397	813
1940	408	25	25	25	25	25	25	610	2264	2628	2607	1156	819
1941	281	25	25	25	25	25	25	1171	1091	1766	1494	432	532
1942	197	25	25	25	25	25	25	950	1450	2476	1920	914	671
1943	312	25	25	25	25	25	25	25	2205	1769	2317	1402	682
1944	249	25	25	25	25	25	528	1457	2035	2597	2546	839	865
1945	249	25	25	25	25	25	284	25	1548	2823	2662	1442	763
1946	293	25	25	25	25	25	25	25	2556	1919	2304	1286	711
1947	67	25	377	156	396	88	1035	2820	1649	2223	2299	1339	1040
1948	25	545	25	25	25	25	25	2590	3945	1979	2003	1343	1046
1949	25	116	25	25	25	25	25	3720	2529	1889	2029	1435	989
1950	228	1284	216	25	25	25	25	2335	4126	2115	2086	1982	1206
1951	932	877	566	138	1048	25	541	3109	2356	2169	2283	1427	1290
1952	25	25	25	25	25	25	25	1745	1615	2207	2239	1593	793
1953	255	25	25	25	25	25	89	1091	2156	1967	2145	1476	775
1954	163	244	314	37	32	25	25	2776	2976	2379	2081	2287	1112
1955	517	640	25	25	25	25	452	216	3704	1797	2298	1721	954
1956	953	1398	226	25	25	25	274	4099	3200	1860	2127	1355	1297
1957	1228	334	1119	25	25	25	25	3112	1558	2397	2299	1571	1144
1958	26	25	25	25	25	25	25	1350	1595	2335	2392	1454	775
Mean	386	250	189	62	85	57	247	1631	2291	2182	2207	1347	911

Table 109. Modified Mean Discharges, in CFS, Yakima River at Cle Elum, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							826	5348	1896	2859	3215	1696	
1929	387	176	161	112	153	398	1687	1535	1943	3140	3372	2044	1259
1930	613	92	159	229	459	691	1134	2029	2472	2179	2041	753	1071
1931	524	166	101	145	293	465	1291	1320	2513	2974	1732	692	1018
1932	597	212	320	345	257	964	1108	2068	3158	2693	3151	2039	1409
1933	662	2355	1028	1278	308	364	566	3145	5857	2393	2777	3245	1998
1934	3065	2499	6046	3115	1763	3312	3760	2567	2568	3180	3272	1839	3082
1935	315	739	592	1558	789	603	919	2727	3116	2646	3169	2121	1608
1936	714	182	148	252	313	566	1331	4270	3605	3013	3281	1852	1627
1937	678	86	226	172	225	408	630	621	3096	2486	2959	1734	1110
1938	608	1082	611	602	259	457	877	3855	2820	2798	3150	2062	1598
1939	509	341	468	685	337	506	1015	1867	2274	3226	3398	2108	1394
1940	779	183	420	185	349	527	585	1075	2556	3312	3444	1797	1268
1941	361	175	315	161	171	301	410	2000	1686	2083	1694	946	859
1942	372	318	431	231	221	270	676	1385	1918	2958	2156	1111	1004
1943	593	321	468	463	297	472	1351	467	2938	1953	2909	2200	1203
1944	476	193	433	180	243	358	1242	2098	2511	3496	3450	887	1297
1945	597	190	242	611	474	304	908	467	1795	3351	3413	2118	1206
1946	672	356	315	397	203	472	847	1161	3360	2158	3007	1950	1242
1947	407	229	1774	919	1041	1216	1881	4081	1555	2766	3187	1862	1743
1948	600	1657	533	324	323	413	580	4182	6958	2367	2559	2313	1901
1949	307	526	353	450	346	564	1385	6893	4118	2499	2772	2376	1882
1950	715	2356	899	676	573	743	892	4498	7168	2714	2751	3171	2263
1951	1468	2477	1925	1003	2697	548	1642	5527	3040	2608	3286	2182	2367
1952	480	432	262	169	308	405	901	2572	1909	2852	2980	2437	1309
1953	515	79	96	717	1026	431	765	1959	2761	2114	2737	2427	1302
1954	400	568	1519	711	564	462	689	4852	4718	2940	2582	3489	1957
1955	867	1348	275	278	699	327	1151	751	6079	2270	3008	2911	1664
1956	1779	3254	1047	481	280	296	1736	7777	5173	1953	2683	1813	2356
1957	2306	866	3608	571	331	380	921	4997	1667	3128	3166	2371	2026
1958	167	155	338	319	643	473	716	2377	1765	3003	3211	1946	1259
Mean	751	787	837	578	532	590	1120	2837	3237	2704	2910	2018	1575

Table 110. Modified Mean Discharges, in CFS, Yakima River at Umatanum, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							2123	6567	2400	3102	3442	2099	
1929	787	538	418	327	380	857	2193	2348	2514	3221	3584	2266	1619
1930	987	254	301	335	641	961	1988	2436	2782	2221	2207	1299	1368
1931	833	341	252	387	654	899	1839	1636	2909	3091	1964	1037	1320
1932	932	508	402	813	989	3016	3000	3460	3914	2889	3298	2274	2125
1933	1072	3182	1672	1855	700	1072	2558	4678	7329	3039	3096	3605	2822
1934	3587	3230	9377	5527	3389	5659	5832	3322	2824	3338	3437	2123	4304
1935	798	1590	1233	3010	2067	1522	2430	4480	4124	2855	3319	2338	2480
1936	1109	484	363	525	874	1728	4466	5985	4734	3242	3530	2235	2440
1937	1117	323	525	467	508	1356	2096	2156	4771	2828	3377	2166	1808
1938	1015	1640	1320	1354	742	1992	3585	5621	3578	2953	3434	2467	2475
1939	948	666	860	1242	706	1522	2212	2711	2655	3372	3621	2353	1906
1940	1124	452	844	499	888	1551	1664	1889	2862	3563	3654	2218	1767
1941	784	519	793	468	776	1353	1570	2356	1948	2004	1919	1308	1316
1942	771	714	967	520	675	855	2007	2265	2402	3237	2337	1373	1510
1943	1000	820	1197	1187	983	1517	4301	1901	4124	2304	3216	2582	2094
1944	940	464	717	341	443	777	1960	2548	2866	3538	3603	1259	1621
1945	964	439	511	1143	1176	740	1861	1766	2316	3507	3727	2449	1717
1946	953	681	691	871	632	1585	2938	3515	4471	2623	3298	2420	2056
1947	854	528	2829	1545	2098	2652	3274	5276	2331	3037	3507	2318	2521
1948	1275	2309	1070	741	807	1007	2072	7273	8929	2764	3094	2671	2834
1949	745	928	748	733	753	2532	4541	9787	5129	2728	3112	2734	2872
1950	1099	2982	1402	899	900	2239	2756	7050	9573	2776	2932	3578	3182
1951	2002	3168	3309	1730	4622	1237	4506	8220	4232	2979	3403	2625	3503
1952	1068	916	719	478	768	1255	2420	3750	2508	3007	3285	2729	1909
1953	899	323	294	1558	2323	1224	2047	4026	3884	2498	3180	2827	2090
1954	803	911	2073	1312	1592	1405	2230	7333	6173	3491	2959	4015	2858
1955	1397	1847	685	574	1125	702	2113	2701	7978	2820	3296	3138	2365
1956	2322	4030	2013	1208	824	2455	6331	11566	7044	2390	3161	2331	3806
1957	2859	1323	4600	865	727	1418	2625	7015	2299	3333	3543	2681	2774
1958	689	4639	709	701	1761	1457	2301	4306	2412	3154	3467	2373	2331
Mean	1191	1358	1430	1107	1184	1618	2857	4446	4187	2958	3184	2384	2325

Table 111. Modified Mean Discharges, in CFS, Bumping River near Nile, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							0	1042	595	465	263	163	
1929	73	94	49	54	47	0	119	272	607	426	241	126	176
1930	33	25	41	46	0	0	304	501	543	281	229	119	177
1931	34	61	44	29	0	0	202	785	434	278	228	109	184
1932	49	118	34	3	151	335	79	805	993	561	395	173	308
1933	60	439	195	65	65	98	0	457	1324	906	486	361	371
1934	367	348	980	467	254	571	595	654	461	286	224	138	445
1935	221	605	140	171	243	210	55	620	1008	512	364	193	362
1936	54	52	34	0	0	0	101	1154	884	459	288	165	266
1937	46	30	60	44	34	0	0	400	1155	558	397	133	238
1938	68	334	257	145	94	101	150	938	908	504	280	126	326
1939	62	62	46	0	20	0	290	787	595	470	244	143	227
1940	42	57	167	0	0	167	440	676	466	273	218	118	219
1941	52	81	83	23	5	0	247	405	345	242	286	49	152
1942	62	190	265	28	16	0	139	496	464	428	239	143	206
1943	36	232	137	26	74	140	271	649	1091	633	436	259	332
1944	57	72	94	26	19	0	126	483	429	262	244	123	161
1945	37	62	37	102	211	104	138	618	578	426	237	182	228
1946	55	97	44	72	43	93	25	1052	1030	646	472	178	317
1947	101	207	366	37	202	210	168	842	503	457	289	166	296
1948	353	291	119	29	103	154	0	652	1215	480	389	190	331
1949	86	126	41	34	0	151	29	1130	1005	641	439	207	324
1950	112	479	171	26	185	311	5	629	1313	885	480	345	412
1951	268	408	483	185	405	184	131	954	845	537	354	145	408
1952	169	170	78	0	57	85	89	859	652	476	286	129	254
1953	29	32	39	244	304	119	13	580	775	676	411	250	289
1954	55	141	247	50	85	141	0	859	941	850	452	378	350
1955	185	262	68	0	47	85	72	122	1146	566	437	303	274
1956	341	496	312	70	73	94	84	1143	1213	793	449	291	447
1957	198	183	307	0	85	172	5	1107	644	460	233	131	294
1958	65	76	31	33	142	146	0	1193	659	455	229	138	264
Mean	112	195	166	67	99	122	129	727	808	515	333	185	288

Table 112. Observed Mean Discharges, in CFS, American River near Nile, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							264	980	492	190	60	65	
1929	50	60	49	37	36	59	117	560	540	192	65	35	150
1930	20	15	41	33	185	120	482	465	335	110	55	30	158
1931	22	35	28	82	132	145	309	752	260	94	53	20	161
1932	32	80	60	91	173	298	365	742	825	350	95	74	265
1933	40	295	150	135	78	86	208	492	1100	725	189	115	301
1934	209	195	715	423	225	507	881	602	260	124	51	45	353
1935	157	500	157	211	216	185	215	682	840	310	79	92	304
1936	35	31	35	56	41	75	427	1068	732	185	79	67	236
1937	31	20	60	32	37	52	195	605	960	350	95	41	206
1938	44	202	230	191	100	89	435	868	753	227	76	35	271
1939	40	47	101	95	65	107	418	725	444	225	69	50	199
1940	32	38	160	140	127	225	416	725	366	107	54	41	203
1941	62	59	113	75	71	181	349	429	263	72	41	50	147
1942	63	118	267	84	55	69	341	425	426	164	58	38	176
1943	32	133	128	72	79	134	595	564	698	428	97	51	251
1944	54	65	107	54	68	110	195	378	320	87	42	35	126
1945	32	46	53	133	174	88	162	675	497	172	59	54	179
1946	43	79	80	98	66	91	346	985	755	443	109	61	263
1947	73	119	286	120	203	246	403	693	406	167	69	57	237
1948	248	246	162	127	104	95	197	803	1014	275	90	59	285
1949	75	75	72	54	57	100	410	1029	723	353	106	64	260
1950	68	270	177	80	98	185	211	687	1060	600	146	70	304
1951	141	272	382	162	296	138	429	821	725	279	81	56	315
1952	107	102	119	69	97	93	409	639	480	239	74	47	206
1953	33	33	33	197	206	116	228	608	588	460	111	52	222
1954	71	97	223	133	100	130	298	838	719	649	214	97	297
1955	98	194	114	80	76	62	103	406	886	375	113	66	214
1956	166	326	229	116	72	85	451	1172	1016	624	151	75	374
1957	85	104	205	73	87	132	270	861	498	145	65	41	214
1958	53	70	76	100	153	156	243	1022	589	146	58	43	226
Mean	74	131	154	112	116	139	337	711	636	291	88	56	237

Table 113. Modified Mean Discharges, in CFS, Tieton River at Tieton Dam near Naches, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							10	1252	879	1218	1200	765	
1929	211	67	106	135	119	10	257	229	620	1239	1180	906	423
1930	306	61	114	132	10	10	64	639	855	894	849	642	381
1931	156	116	80	55	10	10	165	226	815	959	738	570	325
1932	159	15	63	16	10	10	10	167	622	1119	1163	835	349
1933	233	74	117	208	158	10	10	683	1719	1119	1094	992	535
1934	528	516	1844	1096	546	600	400	852	1052	1312	1205	771	894
1935	47	10	10	31	405	65	116	639	1205	1161	1104	835	469
1936	299	55	83	10	10	10	10	577	1239	1218	1184	785	457
1937	296	92	63	115	97	10	10	119	587	1197	1229	815	386
1938	265	10	10	263	218	10	133	1317	1345	1275	1205	850	575
1939	267	35	10	10	58	10	61	237	824	1182	1185	840	393
1940	267	133	10	10	10	10	29	202	1067	1306	1226	978	437
1941	120	25	10	47	18	10	22	577	798	662	629	585	292
1942	156	10	10	52	43	10	10	395	790	1233	938	859	376
1943	111	10	10	10	10	10	10	224	1308	1120	1187	845	405
1944	265	37	10	60	45	10	170	462	998	1341	1195	655	437
1945	163	109	76	10	10	10	121	182	745	998	989	810	352
1946	159	12	10	10	10	10	10	135	965	1112	1169	760	364
1947	101	224	566	236	416	182	20	1221	891	1179	1132	800	581
1948	10	331	50	203	290	42	10	1015	1923	1085	1063	847	572
1949	26	225	10	15	72	21	101	1769	1435	1151	1070	849	562
1950	62	533	104	202	329	244	10	1171	1892	1315	1128	1069	672
1951	460	691	587	392	762	145	176	1472	1267	1220	1179	877	769
1952	10	55	33	106	257	10	10	1133	963	1184	1153	934	487
1953	250	133	132	10	10	10	39	538	1042	1111	1154	894	444
1954	158	160	213	231	259	86	10	1294	1267	1185	1068	1141	589
1955	291	365	10	70	207	10	230	47	1583	899	1171	894	481
1956	439	716	442	272	226	10	255	1989	1911	1215	1197	807	790
1957	420	292	286	135	211	89	10	1356	904	1280	1127	926	586
1958	154	32	13	10	10	10	10	1122	1010	1327	1215	881	483
Mean	213	171	169	138	161	56	83	733	1121	1150	1104	838	495

Table 114. Modified Mean Discharges, in CFS, Naches River below Tieton River near Naches, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							1037	5221	2274	1717	1128	667	
1929	377	301	301	272	245	345	818	2109	2217	1646	1037	709	865
1930	358	129	301	265	445	597	1995	2003	1820	1005	655	444	835
1931	228	289	218	301	317	338	1326	2776	1541	989	598	461	782
1932	231	301	301	301	792	1476	1610	3244	3134	1898	1288	718	1274
1933	346	1472	954	720	443	398	1618	3281	6217	3259	1590	1218	1793
1934	1211	1464	7099	4063	2143	3296	3397	2634	1850	1450	1167	1064	2570
1935	569	1734	956	1489	1736	847	1309	3820	4027	1963	1275	803	1711
1936	361	284	301	566	577	828	2845	5415	4224	2216	1756	1155	1710
1937	382	207	301	301	301	356	1022	2904	4029	2055	1372	736	1164
1938	429	882	1028	1254	760	904	2654	5324	3960	1896	1263	716	1756
1939	449	301	379	366	301	611	1795	2420	1881	1522	1081	692	983
1940	359	301	602	306	445	1101	1923	2646	1933	1333	1093	832	1073
1941	271	301	467	301	301	709	1449	1711	1371	659	558	430	711
1942	380	553	1053	301	301	374	1603	1980	2091	1624	855	637	979
1943	177	644	715	551	517	876	3491	3176	4595	2478	1478	830	1627
1944	413	301	463	301	290	367	929	1857	1864	1400	1101	506	816
1945	234	301	301	621	870	437	936	2925	2213	1356	925	711	986
1946	309	376	390	470	329	637	1775	4701	3684	2220	1450	518	1405
1947	369	709	2088	751	1525	1631	1971	4467	2314	1637	1187	803	1621
1948	958	1471	813	732	874	680	1262	5189	6743	2060	1312	810	1909
1949	351	632	372	301	429	935	2550	7200	4382	2169	1416	913	1804
1950	351	1773	893	566	898	1449	1469	5020	7109	3572	1569	1198	2156
1951	1101	2123	2706	1496	2847	1166	2891	5917	3721	1896	1296	773	2328
1952	429	528	504	351	795	590	1943	3956	2539	1793	1176	741	1279
1953	311	244	301	1073	1295	618	1134	3415	3487	2416	1367	857	1376
1954	351	529	1177	820	904	886	1521	5602	4469	3325	1584	1410	1882
1955	728	1055	385	328	520	315	713	1860	5607	2037	1398	976	1327
1956	1210	2402	1868	880	671	793	3834	8779	6323	3028	1572	938	2692
1957	824	825	1537	442	634	849	1519	5776	2402	1637	1111	788	1529
1958	351	301	301	387	958	880	1474	5898	2706	1691	1148	825	1410
Mean	481	758	969	696	782	843	1826	3934	3482	1942	1222	802	1478

Table 115. Observed Mean Discharges, in CFS, N. F. Ahtanum Creek near Tampico, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							119	239	103	37	19	15	
1929	21	24	18	16	9	31	50	134	109	37	18	13	40
1930	14	13	16	8	50	47	121	114	70	26	15	13	42
1931	12	11	11	14	15	12	61	118	38	17	10	10	27
1932	12	13	13	15	27	62	94	188	153	45	21	15	55
1933	15	31	26	16	15	25	103	159	280	112	34	23	70
1934	24	27	175	163	103	117	184	142	72	30	18	16	89
1935	27	72	51	81	81	52	99	210	169	52	24	17	78
1936	16	16	14	14	8	24	113	200	112	34	17	15	49
1937	14	14	16	10	12	25	89	182	166	51	23	19	52
1938	17	28	31	49	29	73	196	283	209	63	29	19	86
1939	20	19	19	16	16	40	82	110	60	22	14	12	36
1940	12	12	18	13	30	71	114	168	82	26	16	14	48
1941	15	17	16	16	19	73	112	106	60	20	15	14	40
1942	14	17	48	21	19	48	134	143	105	38	18	14	52
1943	14	26	35	32	36	64	178	169	200	93	34	21	75
1944	21	21	16	14	15	28	46	86	51	18	12	10	28
1945	11	11	9	12	26	22	65	145	94	24	14	13	37
1946	12	12	16	16	16	43	91	220	152	58	24	17	56
1947	16	26	95	21	56	68	112	216	114	37	20	18	67
1948	36	42	32	25	33	44	107	287	368	82	42	25	94
1949	24	24	22	19	31	66	165	308	208	66	30	24	82
1950	22	29	26	14	22	59	123	228	300	131	38	26	85
1951	32	56	104	66	136	71	216	308	232	72	35	25	113
1952	28	25	31	22	33	49	158	204	138	50	24	20	65
1953	16	14	16	71	61	41	99	209	182	92	32	22	71
1954	21	23	31	29	45	58	128	245	298	130	42	26	90
1955	26	32	24	21	21	22	38	125	210	59	28	21	52
1956	27	37	65	42	29	73	295	427	328	128	47	31	127
1957	27	27	36	19	27	51	118	271	118	36	25	18	65
1958	23	19	23	25	74	64	126	331	162	57	27	21	79
Mean	20	25	35	30	36	51	121	201	161	56	25	18	65

Table 116. Observed Mean Discharges, in CFS, S. F. Ahtanum Creek at Conrad Ranch near Tampico, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							35	57	25	10	8	6	
1929	6	7	6	5	4	11	12	29	22	9	5	5	10
1930	5	5	6	3	18	18	24	25	13	7	4	4	11
1931	5	4	4	5	6	6	13	22	9	5	4	4	7
1932	4	4	4	5	14	24	24	46	32	12	8	6	15
1933	6	8	7	6	5	11	30	37	72	23	11	8	19
1934	8	8	72	72	32	30	54	36	16	9	6	5	29
1935	9	20	19	37	27	20	30	57	44	14	9	7	24
1936	6	7	6	6	5	11	28	48	29	10	6	6	14
1937	5	5	6	4	4	14	40	46	37	13	7	6	16
1938	5	7	11	16	9	34	62	68	50	15	9	7	24
1939	7	7	6	6	6	12	18	29	14	7	4	4	10
1940	4	5	6	5	11	26	26	37	16	7	5	4	13
1941	4	5	5	5	8	21	23	22	11	6	5	5	10
1942	5	6	14	7	8	21	36	36	25	10	7	6	15
1943	5	10	12	11	13	26	60	47	63	25	12	8	24
1944	8	8	6	4	5	8	12	20	13	6	4	4	8
1945	4	4	4	4	8	8	17	32	21	8	6	5	10
1946	5	5	6	6	7	17	25	51	38	15	8	6	16
1947	6	9	37	9	23	21	28	53	29	11	7	7	20
1948	9	9	8	6	12	20	37	77	114	26	15	11	29
1949	9	9	8	8	13	29	47	81	60	17	10	8	25
1950	7	7	7	5	8	27	35	52	81	33	12	8	24
1951	10	17	34	20	56	23	54	79	58	20	12	9	33
1952	9	9	9	6	14	17	40	47	32	13	9	7	18
1953	6	6	6	27	20	12	23	48	49	22	11	8	20
1954	7	7	9	10	16	19	33	58	57	31	13	9	22
1955	9	10	8	7	7	8	12	26	47	15	8	7	14
1956	8	10	24	15	11	39	92	100	86	34	16	12	37
1957	10	10	13	7	10	22	35	56	25	11	8	7	18
1958	8	7	8	9	35	23	40	79	44	18	11	9	24
Mean	7	8	12	11	14	19	34	48	40	15	8	7	19

Table 117. Modified Mean Discharges, in CFS, Yakima River near Parker, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							860	7852	155	125	125	125	
1929	125	908	959	870	1037	1163	125	125	125	125	125	125	484
1930	125	555	889	751	1635	1428	936	125	125	127	120	125	578
1931	117	793	743	774	1073	31	125	125	125	122	111	141	357
1932	125	1101	959	1431	2058	4896	2005	2580	2566	125	125	125	1508
1933	125	5161	2919	3023	1592	1537	1427	3771	9146	1504	125	2126	2705
1934	3496	5094	16507	10013	6273	8309	6029	1756	125	125	125	125	4832
1935	125	3914	2424	4893	4582	2076	125	3748	3746	125	125	125	2167
1936	125	1029	855	965	761	2159	3872	6263	4074	125	125	125	1706
1937	125	876	1115	920	893	1650	1032	200	4513	125	125	125	975
1938	125	2792	2722	2940	1880	3587	4301	6779	3392	125	125	125	2408
1939	125	1269	1444	1828	1239	1839	139	808	125	125	125	125	766
1940	125	911	1514	909	1693	2629	661	130	125	125	127	126	763
1941	124	1045	1613	1034	1300	1860	240	125	126	125	127	125	654
1942	125	1457	2369	1070	1345	1081	713	125	125	125	125	125	732
1943	124	1733	2130	2052	1851	2379	6057	767	4370	125	125	464	1850
1944	132	1166	1486	852	1014	1008	125	125	125	127	127	126	534
1945	128	1010	1029	2005	2321	980	125	125	125	125	125	125	685
1946	125	1400	1392	1707	1266	2272	2024	3920	4050	125	125	353	1563
1947	167	1486	5476	2646	3970	3807	1538	4956	262	125	125	125	2058
1948	1171	4035	2207	1693	1959	1475	1022	8886	11812	125	125	373	2907
1949	203	1818	1254	891	1507	3659	4682	12592	5089	125	125	405	2696
1950	354	4948	2564	1202	2249	3579	2161	7623	12756	2249	125	1624	3453
1951	2307	5590	6574	3831	8547	3371	5158	10028	3896	125	125	125	4140
1952	576	1726	1450	964	1885	1790	1376	3418	634	125	125	125	1183
1953	125	849	842	3015	4022	1154	125	3572	3242	125	125	494	1474
1954	195	1708	3494	2094	2661	2021	840	8668	6136	2276	125	2333	2713
1955	1130	3230	1314	1197	1883	675	125	345	8815	281	125	1025	1679
1956	2623	6766	4411	2553	1773	4193	9133	16646	9356	857	125	125	4880
1957	2720	2455	6190	1472	1849	2576	2461	9094	250	125	125	125	2454
1958	382	1027	4735	1332	3282	2380	2410	6455	521	125	125	125	1908
Mean	586	2264	2786	2031	2313	2385	2037	4129	3330	343	125	125	1894

Table 118. Modified Mean Discharges, in CFS, Yakima River at Kiona, Washington

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928							2412	9072	2239	2068	1821	1969	
1929	1656	2065	1924	1719	1846	2435	1394	1457	2190	1756	1729	2042	1851
1930	1734	1722	1886	1775	2795	2624	2413	1922	1950	1534	1487	1525	1947
1931	1548	1730	1536	1339	1637	925	1268	1905	2042	1566	1144	1254	1491
1932	1246	1573	1570	2072	2098	6745	3226	4127	4202	1862	1590	1057	2610
1933	572	4090	2300	2383	2084	2452	2370	4080	11009	3188	1534	3654	3310
1934	4833	5946	17995	12038	7901	9209	6682	5139	1426	1385	1527	1702	6315
1935	1454	5039	3379	5461	6015	3287	1334	5129	5709	1680	1486	1778	3479
1936	1590	2138	1707	1944	1488	3180	4832	7571	6491	1578	1437	1668	2969
1937	1549	1943	1892	1591	1649	2789	2869	1600	6696	2040	1780	2105	2375
1938	1645	3777	3975	4640	3133	5596	6010	8740	5924	1828	1682	1746	4058
1939	1752	2261	2275	2577	1976	2567	1218	1691	1825	1517	1486	1720	1905
1940	1682	2023	2418	1746	2973	4366	2130	1674	1742	1544	1636	1849	2149
1941	1621	2078	2572	2099	2308	2948	1481	1382	1459	1181	1230	1568	1825
1942	1434	2065	3058	1541	2086	2009	1892	1614	1878	1621	1316	1426	1828
1943	1492	2724	3321	3289	3279	3470	7930	2355	6055	1961	1780	2021	3306
1944	1687	2169	2362	1663	1723	1800	930	1196	1730	1538	1595	1377	1648
1945	1488	1942	1693	2517	3047	1759	1218	1261	2010	1457	1660	1648	1808
1946	1426	2200	1992	2819	2063	3437	3184	5103	6738	1888	1621	2244	2893
1947	1759	2447	6676	3614	5218	5146	2993	6861	2549	1517	1562	1825	3514
1948	2844	4976	3186	2985	3311	3048	3010	9454	15877	1932	1794	2076	4541
1949	1764	2778	1885	1414	2491	5291	6845	14223	7156	1624	1658	1992	4093
1950	1777	5715	3561	2023	3230	5498	4329	9012	15504	3897	1417	2837	4900
1951	3736	6525	8067	5126	10383	4808	7203	12207	6457	1634	1562	1924	5803
1952	2349	2777	2429	1764	3440	2998	3120	5313	2617	1712	1682	1881	2674
1953	1585	1828	1669	4866	5446	2607	1324	5525	5505	1554	1628	2094	2969
1954	1596	2155	4207	2842	3950	3810	2936	10691	8341	4143	1732	4062	4205
1955	2739	4118	2146	1897	2582	1576	1380	2081	10254	2124	1537	2736	2931
1956	4255	7670	6443	4718	3013	6076	11718	19033	12796	2548	1821	2134	6852
1957	4413	3488	6962	2185	2625	3976	4724	11157	2026	1450	1600	1908	3876
1958	2294	2044	958	2344	4534	4124	4593	7847	2125	1385	1520	1946	2976
Mean	2051	3134	3533	2966	3344	3685	3552	5712	5409	1911	1584	1994	3240

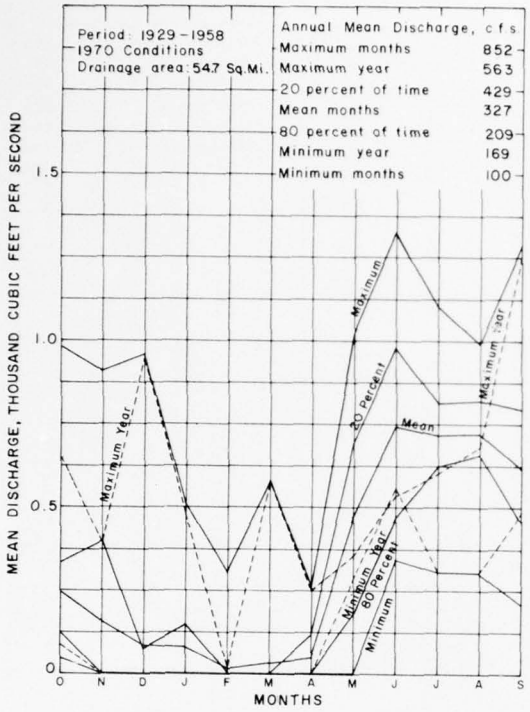


Figure 188 Monthly discharge, Yakima River near Martin

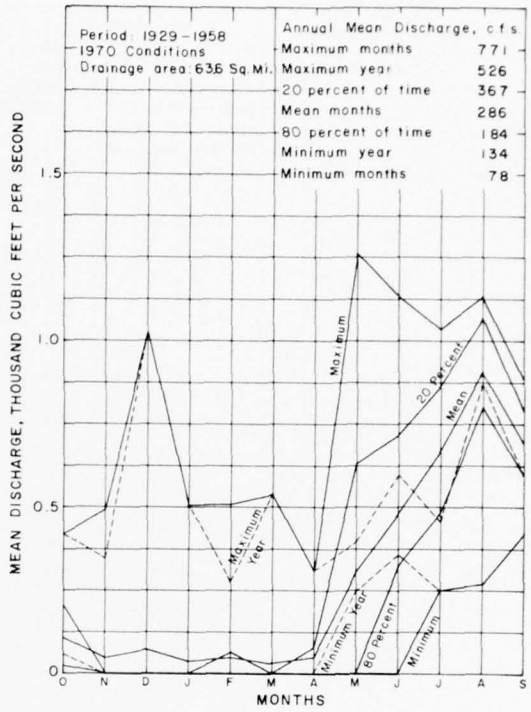


Figure 189 Monthly discharge, Kachess River near Easton

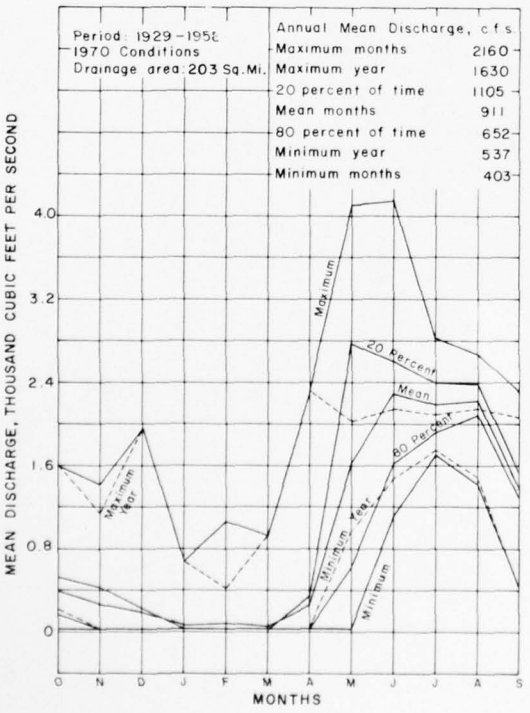


Figure 190 Monthly discharge, Cle Elum River near Roslyn

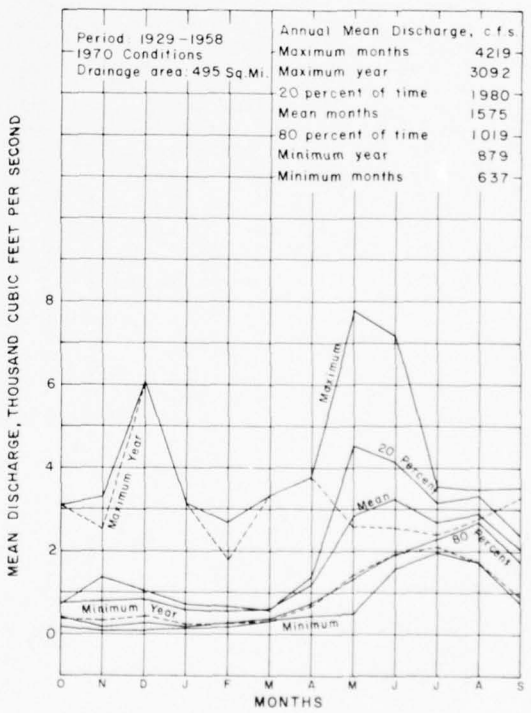


Figure 191 Monthly discharge, Yakima River at Cle Elum

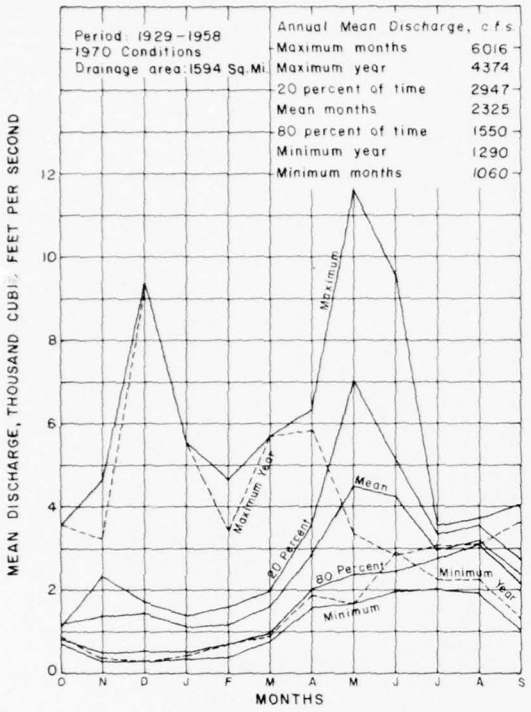


Figure 192 Monthly discharge, Yakima River at Umtanum

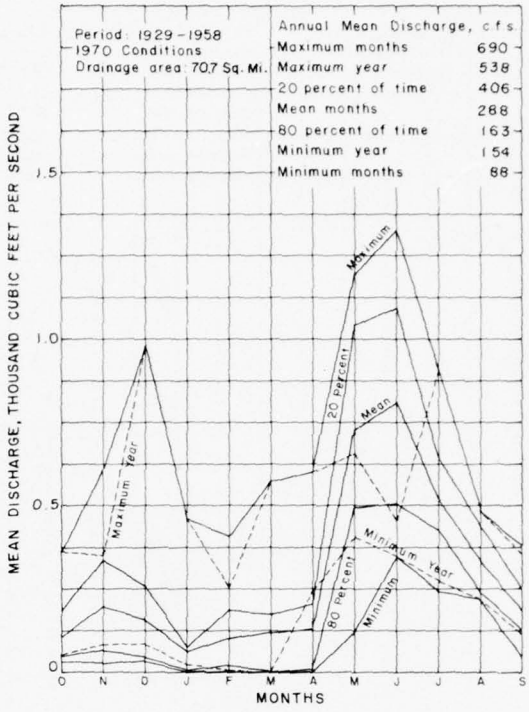


Figure 193 Monthly discharge, Bumping River near Nile

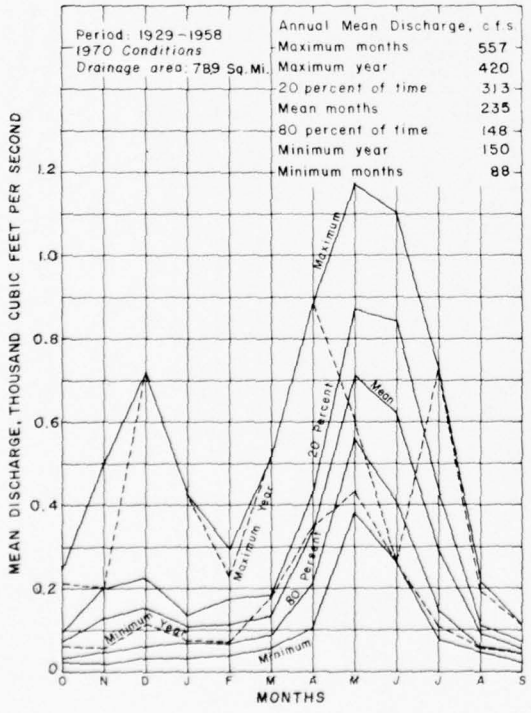


Figure 194 Monthly discharge, American River near Nile

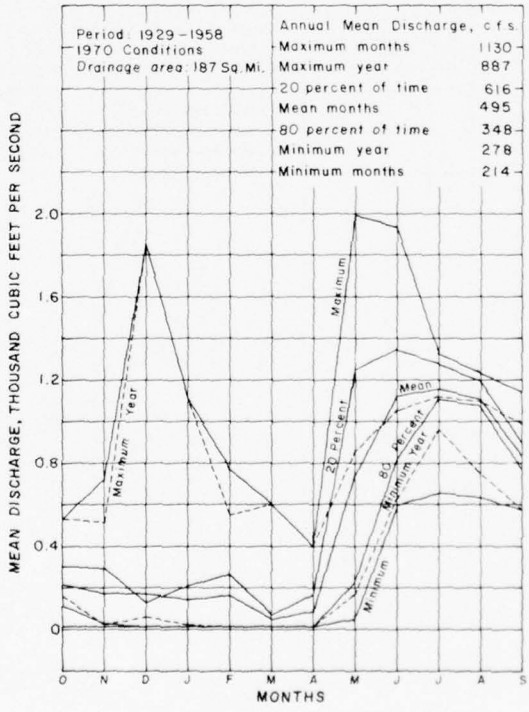


Figure 195 Monthly discharge, Tieton River at Tieton Dam near Naches

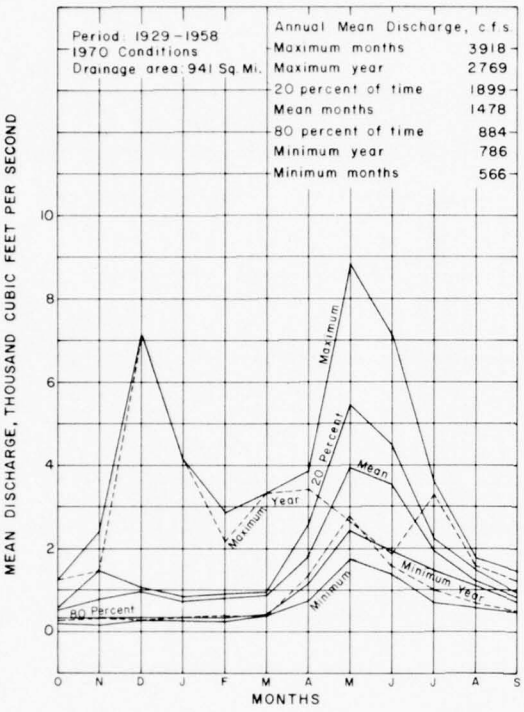


Figure 196 Monthly discharge, Naches River below Tieton River near Naches

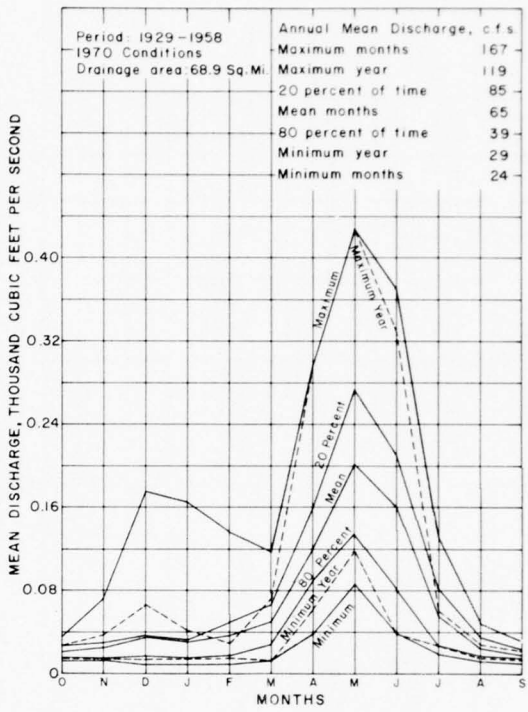


Figure 197 Monthly discharge, N.F. Ahtanum Creek near Tampico

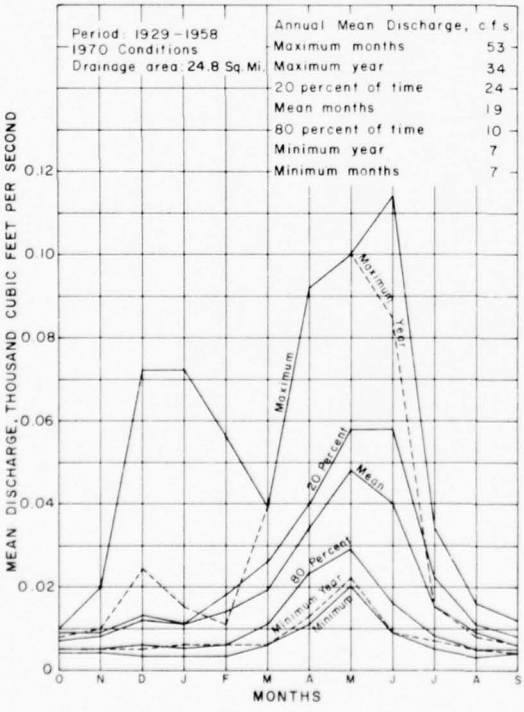


Figure 198 Monthly discharge, S.F. Ahtanum Creek at Conrad Ranch near Tampico

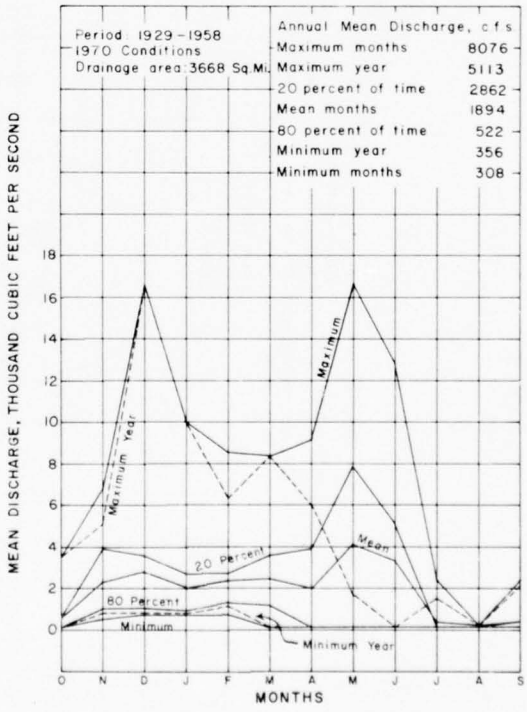


Figure 199 Monthly discharge, Yakima River near Parker

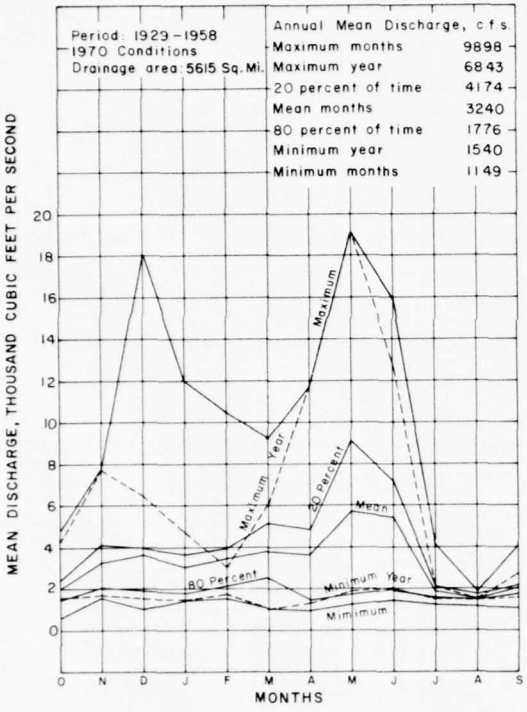


Figure 200 Monthly discharge, Yakima River at Kiona

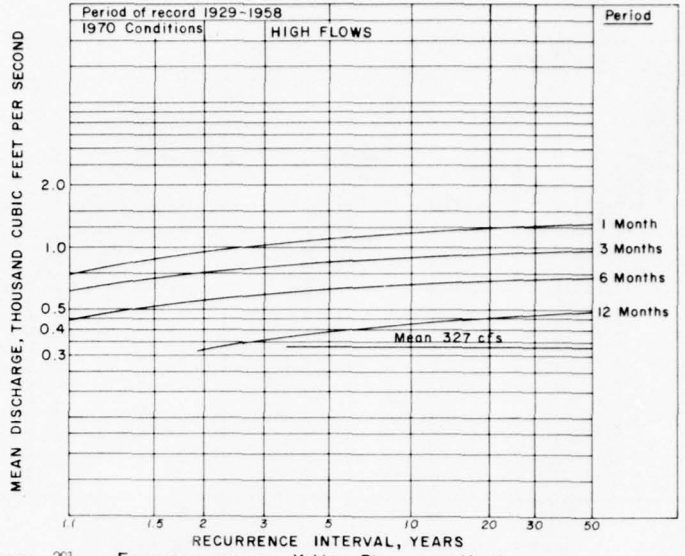


Figure 201 Frequency curves, Yakima River near Martin

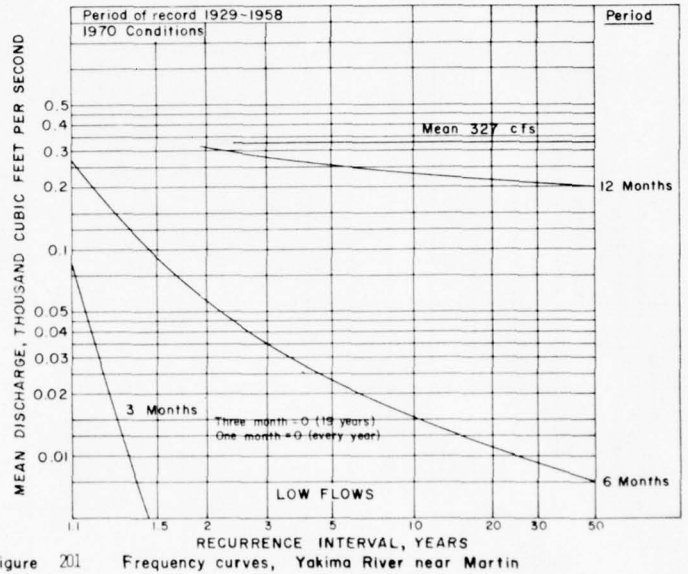


Figure 201 Frequency curves, Yakima River near Martin

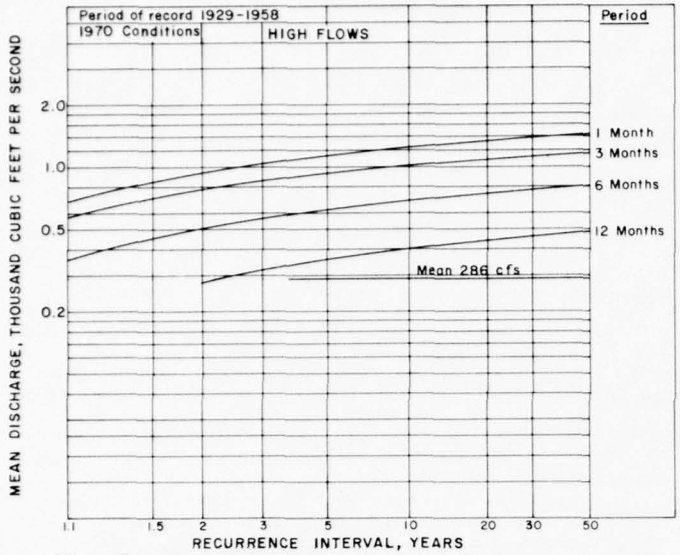


Figure 202 Frequency curves, Kachess River near Easton

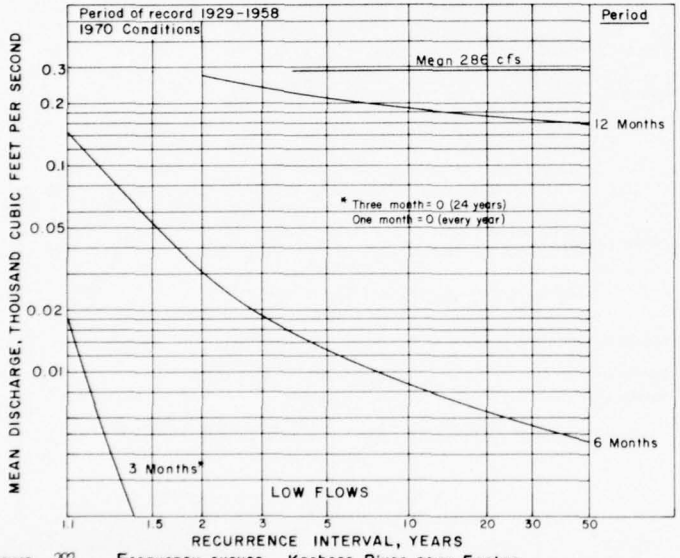


Figure 202 Frequency curves, Kachess River near Easton

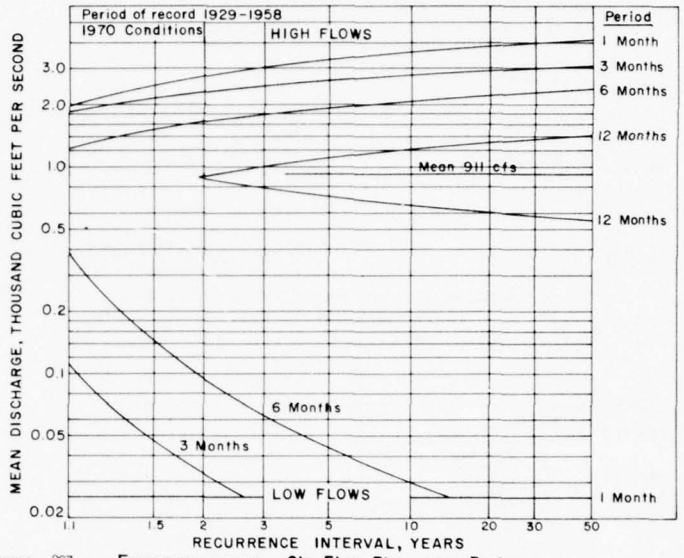


Figure 203 Frequency curves, Cle Elum River near Roslyn

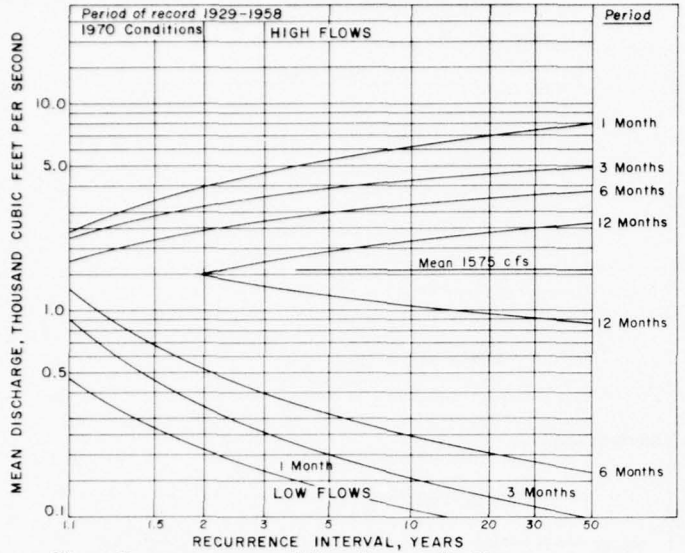


Figure 204 Frequency curves, Yakima River at Cle Elum

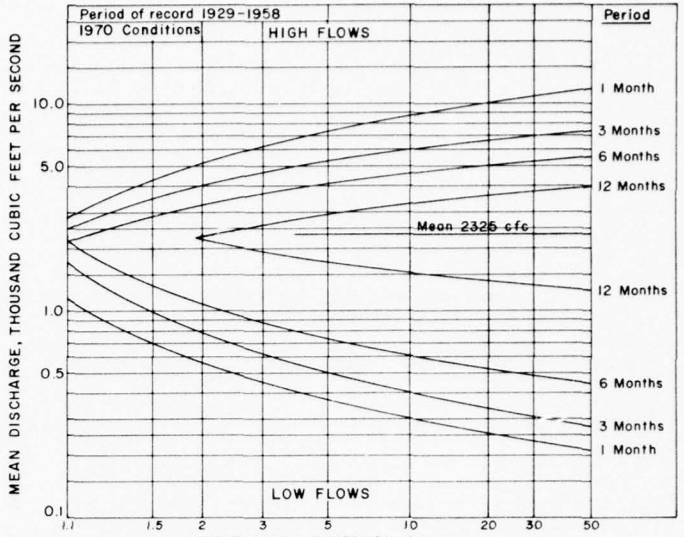


Figure 205 Frequency curves, Yakima River at Umtanum

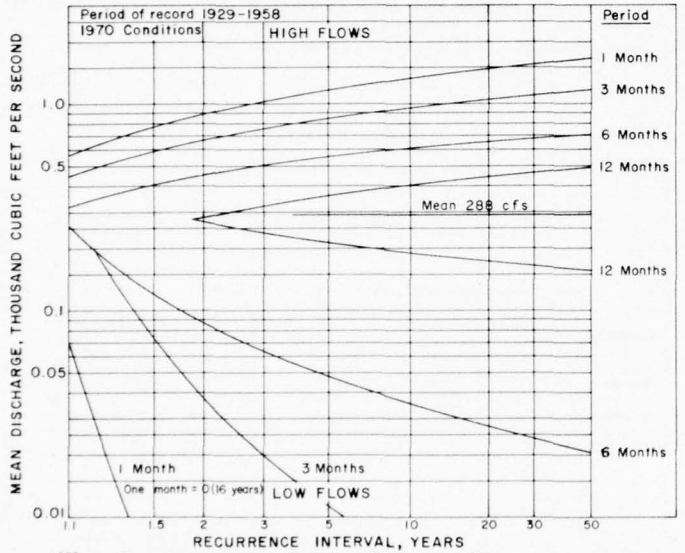


Figure 206 Frequency curves, Bumping River near Nile

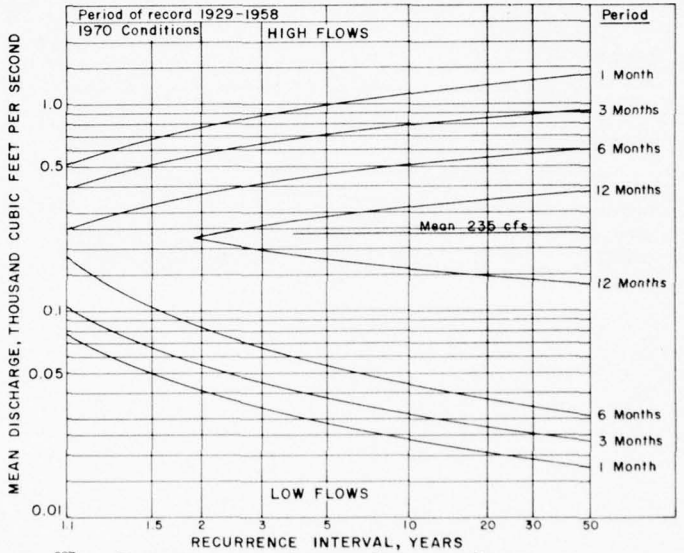


Figure 207 Frequency curves, American River near Nile

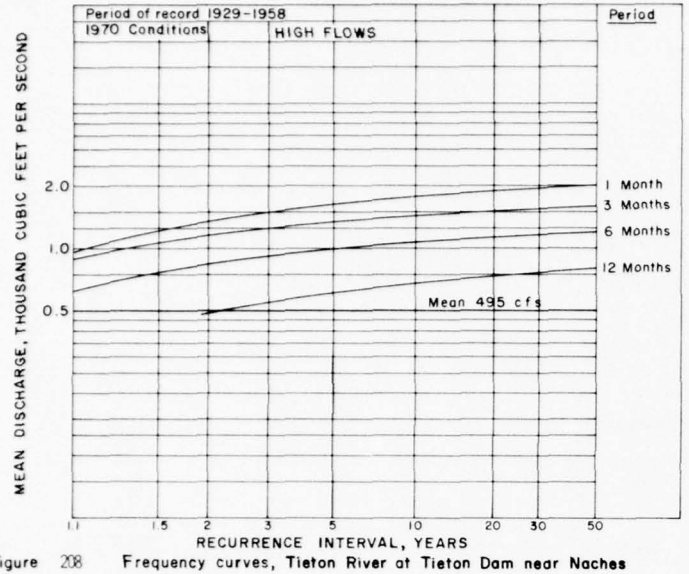


Figure 208 Frequency curves, Tieton River at Tieton Dam near Naches

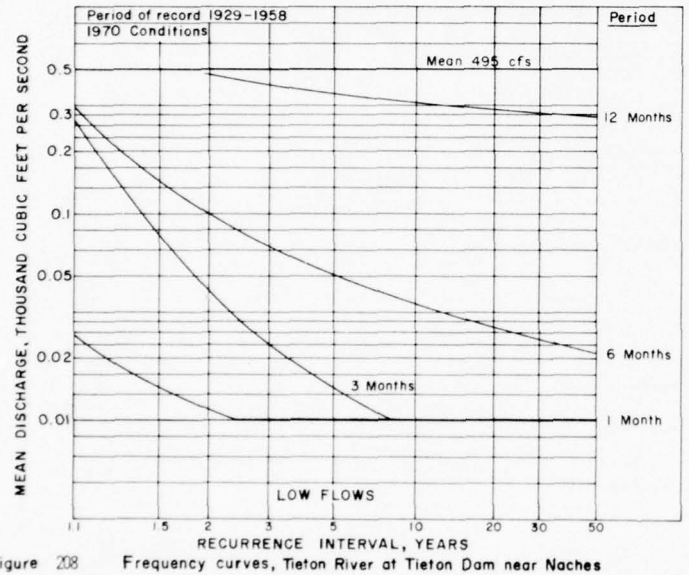


Figure 208 Frequency curves, Tieton River at Tieton Dam near Naches

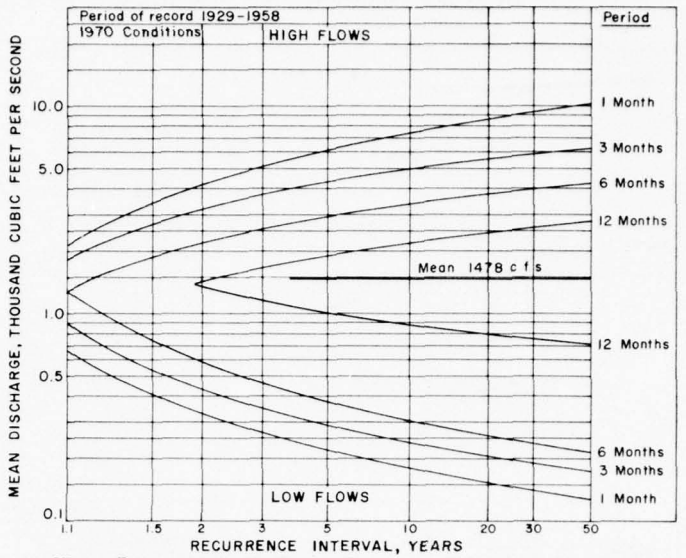


Figure 209 Frequency curves, Naches River below Tieton River near Naches

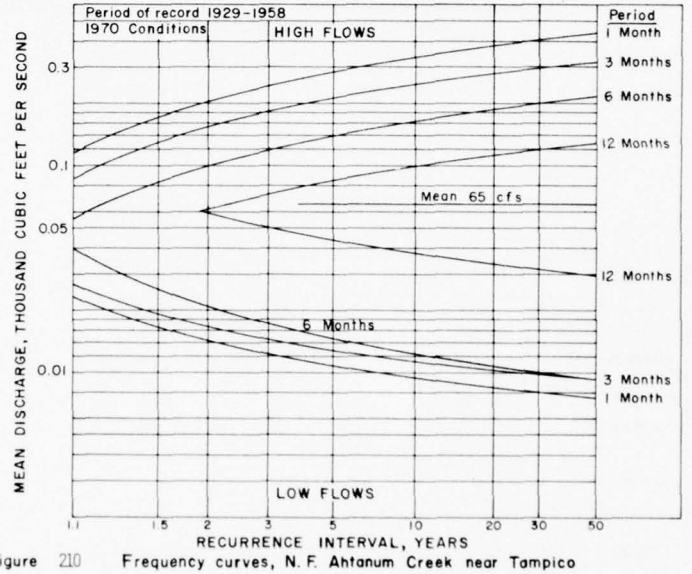


Figure 210 Frequency curves, N. F. Ahtanum Creek near Tampico

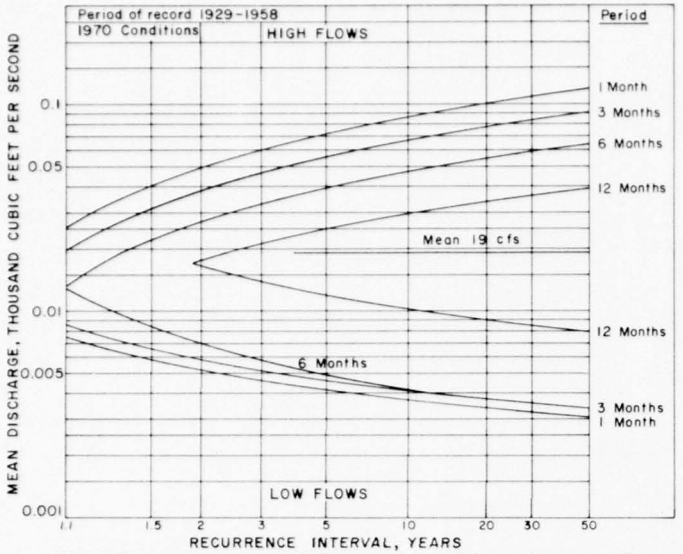


Figure 211 Frequency curves, S.F. Ahtanum Creek at Conrad Ranch near Tampico

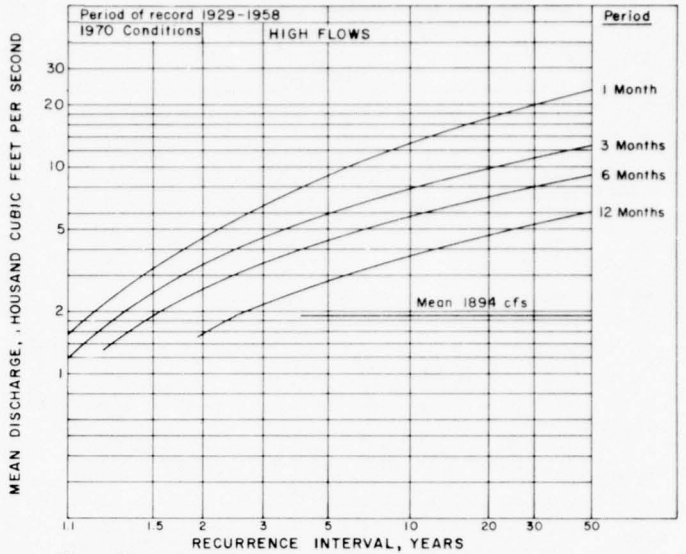


Figure 212 Frequency curves, Yakima River near Parker

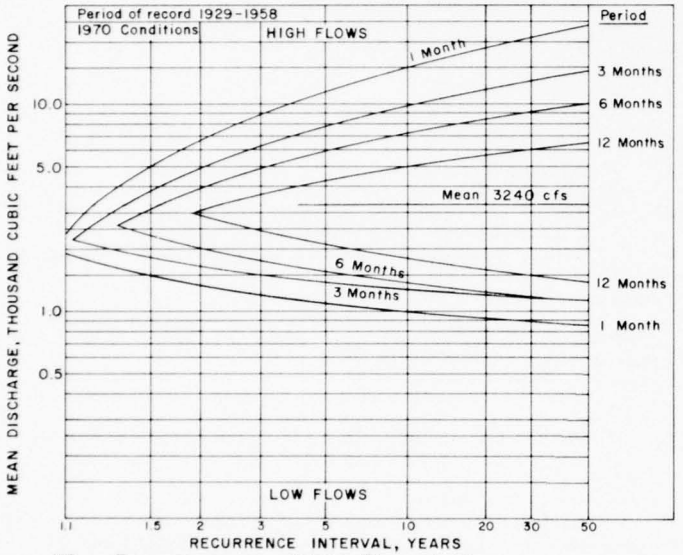


Figure 213 Frequency curves, Yakima River at Kiona

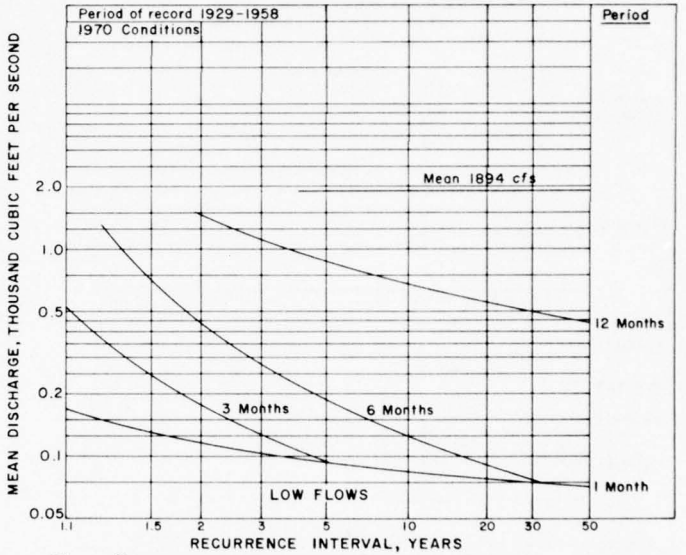


Figure 212 Frequency curves, Yakima River near Parker

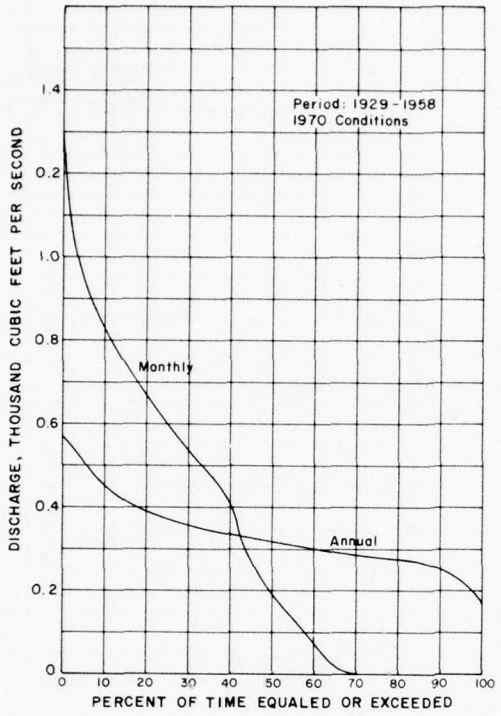


Figure 214 Duration curves, Yakima River near Martin

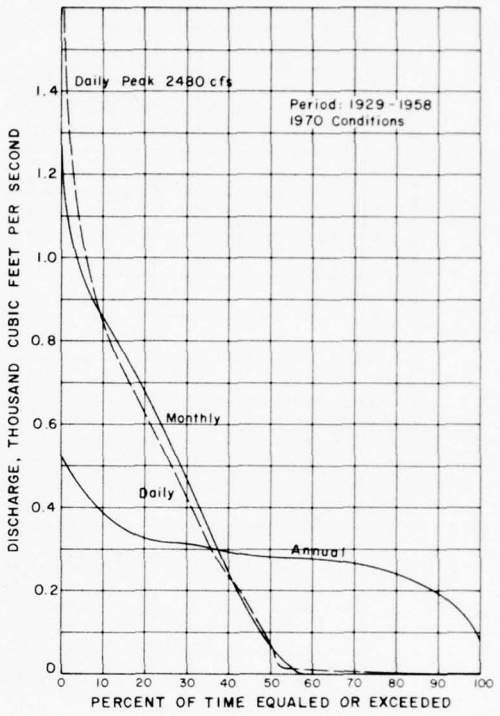


Figure 215 Duration curves, Kachess River near Easton

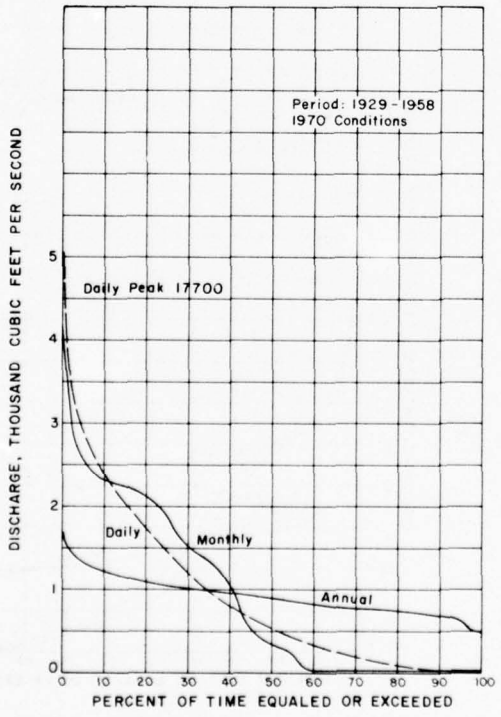


Figure 216 Duration curves, Cle Elum River near Roslyn

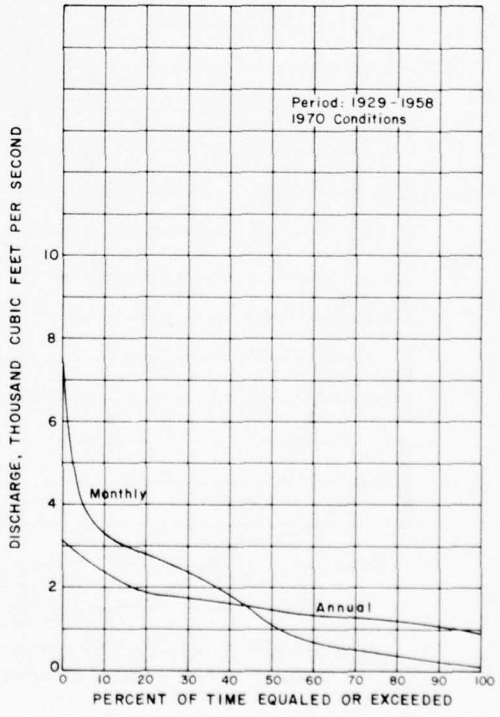


Figure 217 Duration curves, Yakima River at Cle Elum

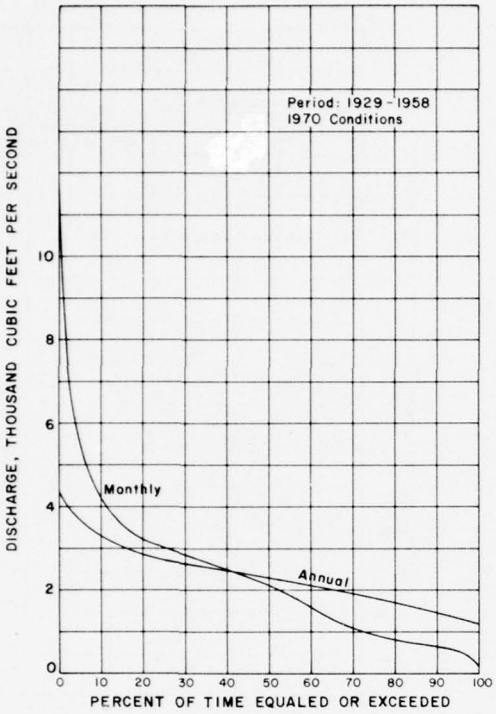


Figure 218 Duration curves, Yakima River at Umtanum

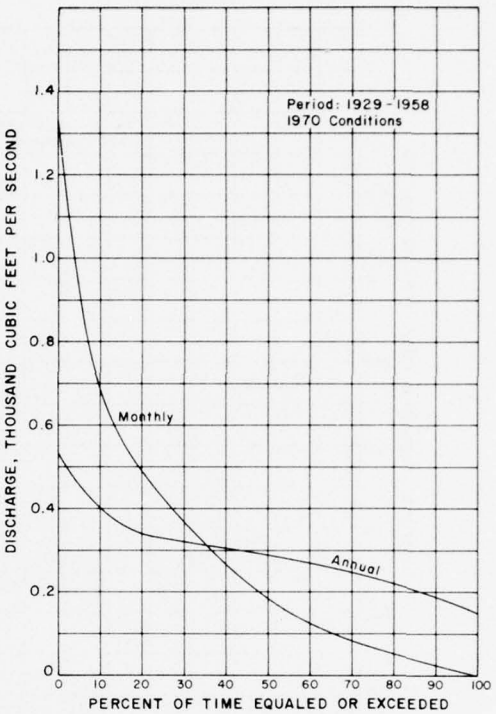


Figure 219 Duration curves, Bumping River near Nile

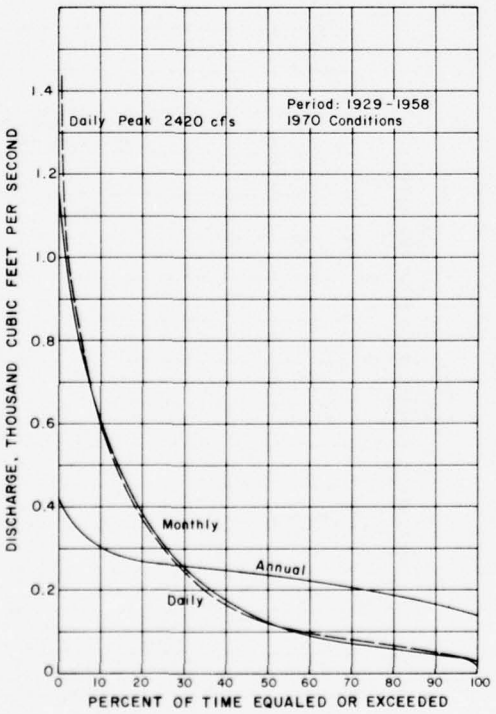


Figure 220 Duration curves, American River near Nile

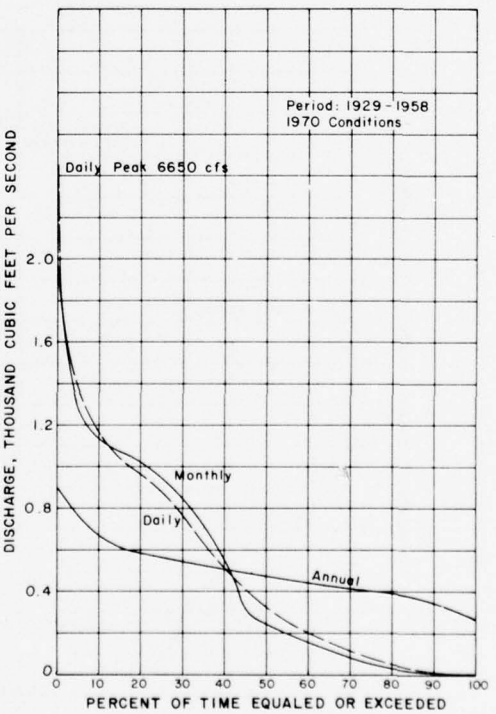


Figure 221 Duration curves, Tieton River at Tieton Dam Near Naches

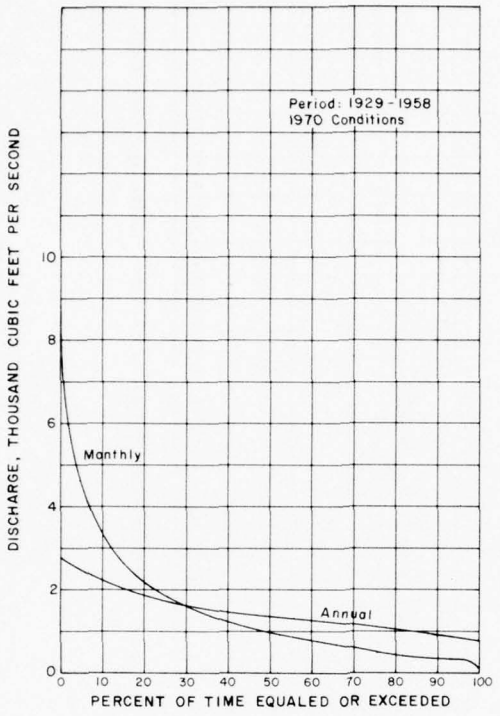


Figure 222 Duration curves, Naches River below Tieton River near Naches

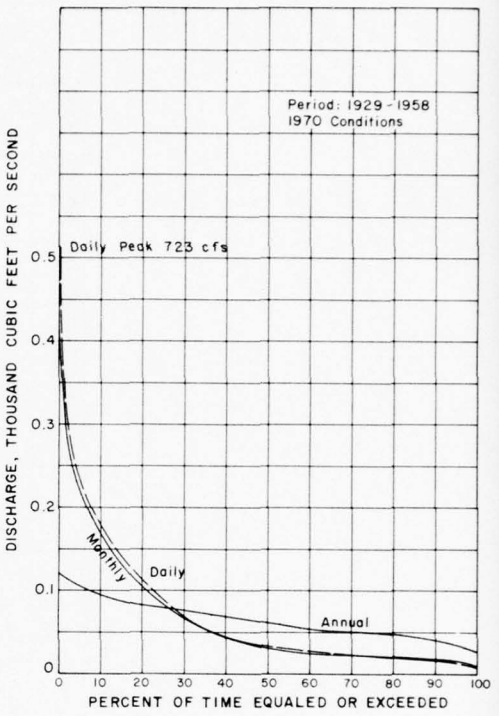


Figure 223 Duration curves, N.F. Ahtanum Creek near Tampico

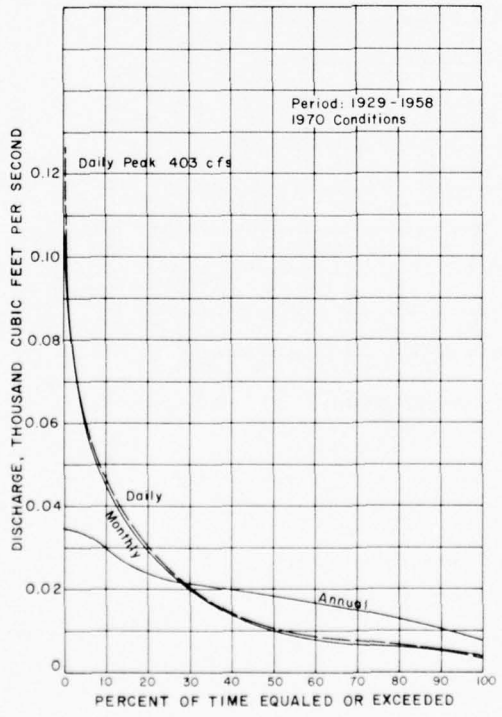


Figure 224 Duration curves, S.F. Ahtanum Creek at Conrad Ranch near Tampico

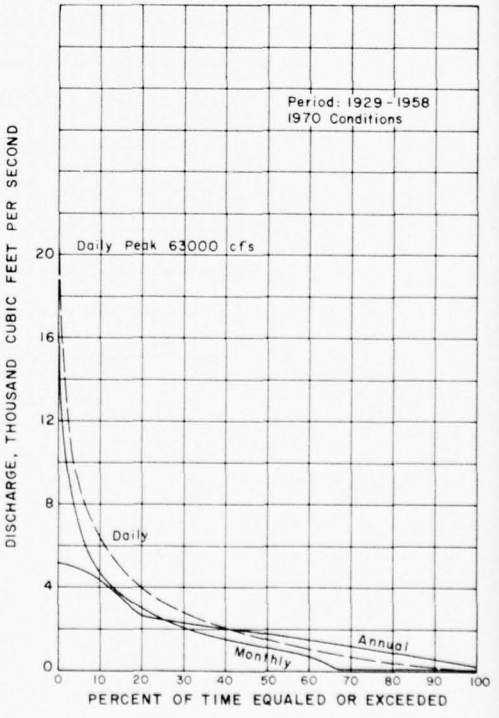


Figure 225 Duration curves, Yakima River near Parker

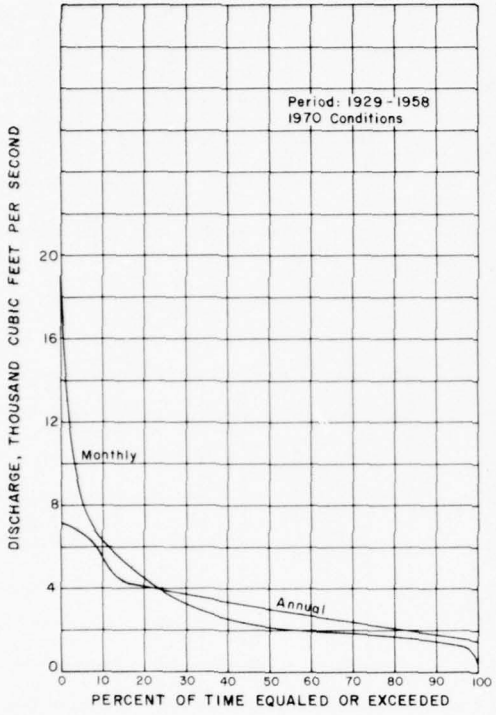


Figure 226 Duration curves, Yakima River at Kiona

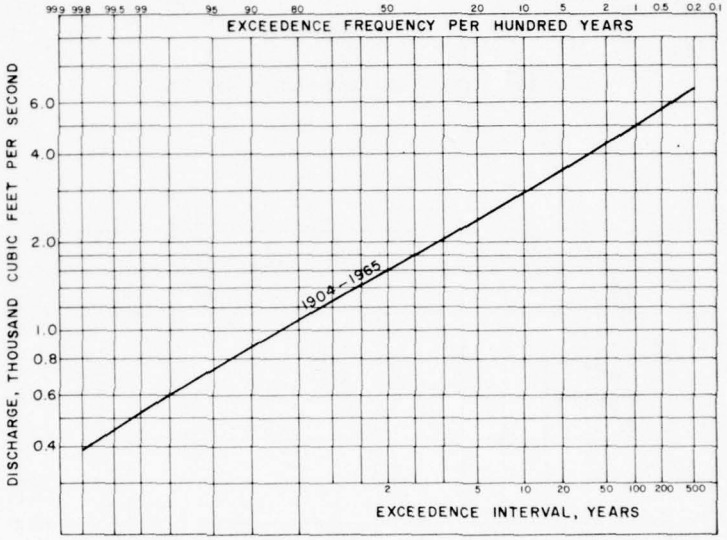


Figure 227 Frequency curve of annual peak flows, Yakima River near Martin

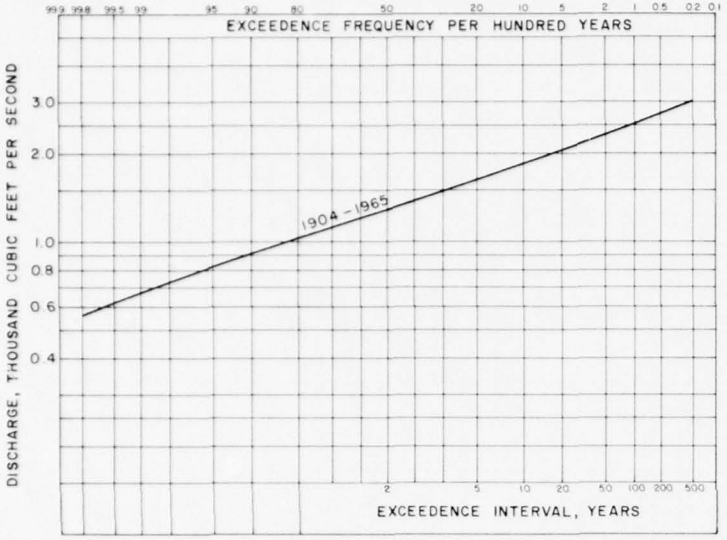


Figure 228 Frequency curve of annual peak flows, Kachess River near Easton

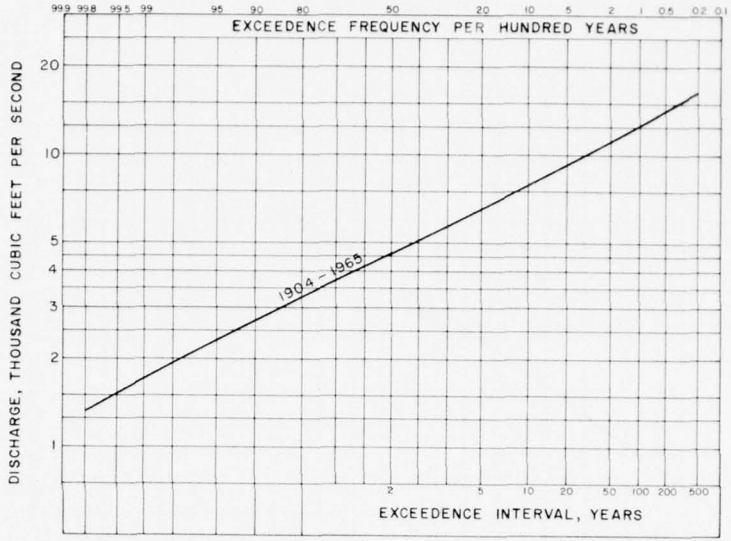


Figure 229 Frequency curve of annual peak flows, Cle Elum River near Roslyn

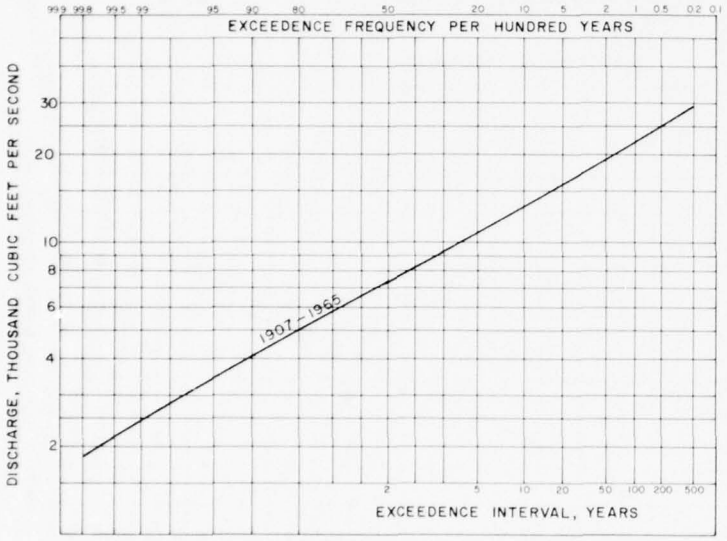


Figure 230 Frequency curve of annual peak flows, Yakima River at Cle Elum

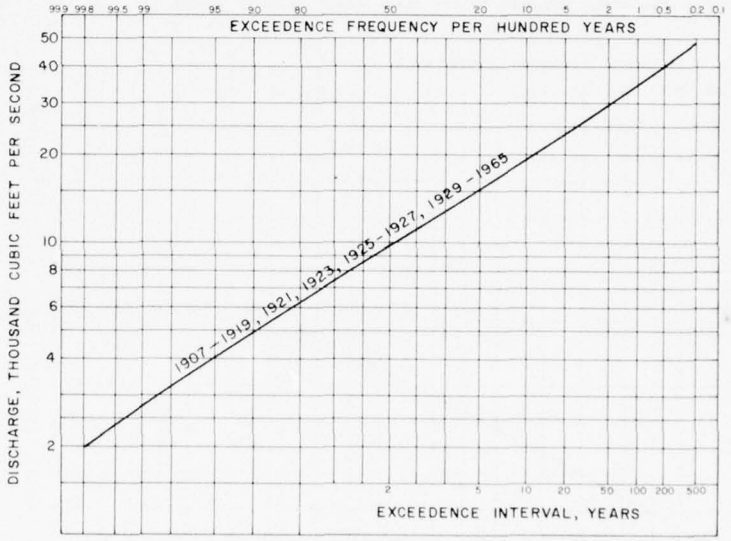


Figure 231 Frequency curve of annual peak flows, Yakima River at Umtanum

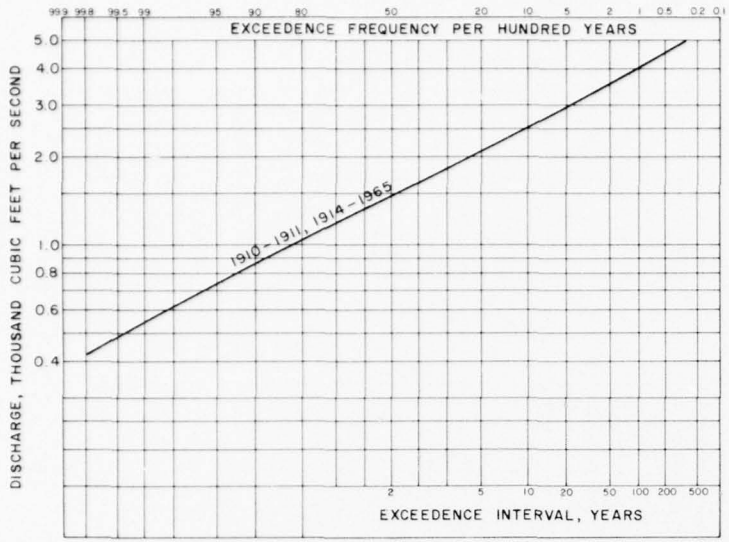


Figure 232 Frequency curve of annual peak flows, Bumping River near Nile

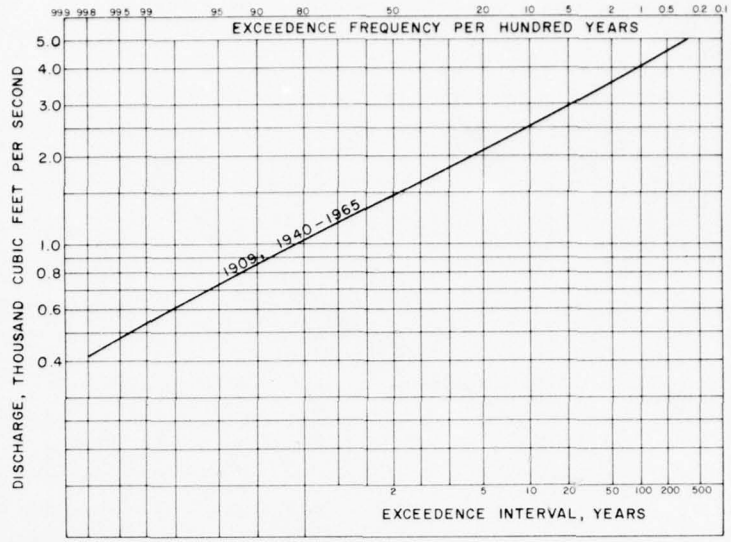
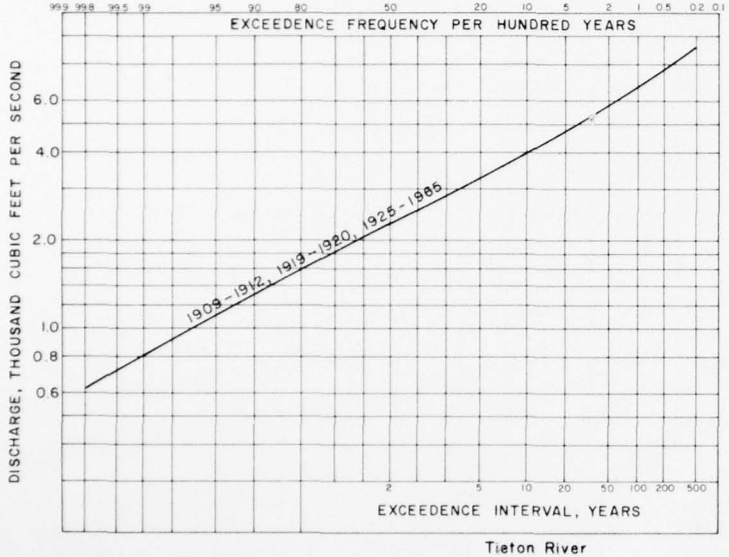
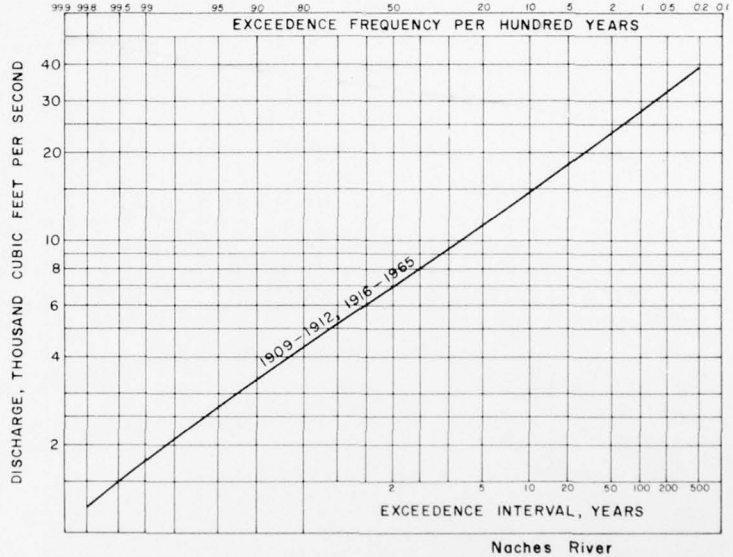


Figure 233 Frequency curve of annual peak flows, American River near Nile



Tieton River

Figure 234 Frequency curve of annual peak flows, at Tieton Dam near Naches



Naches River

Figure 235 Frequency curve of annual peak flows, below Tieton River near Naches

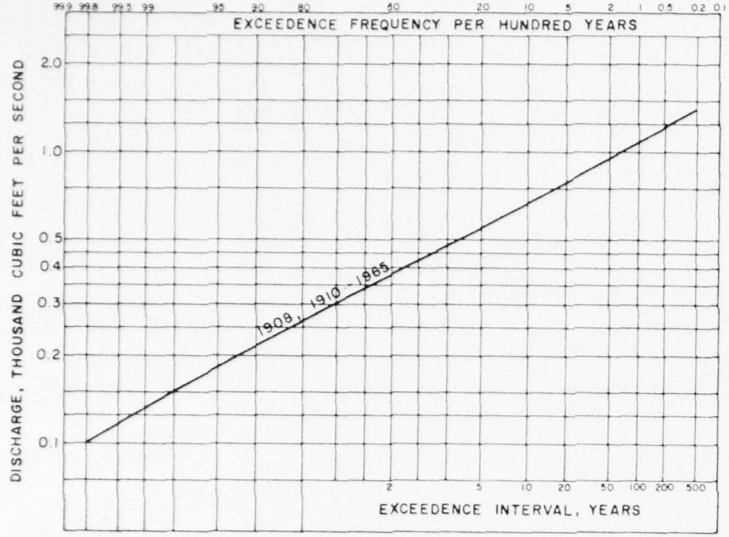


Figure 236 Frequency curve of annual peak flows, N.F. Ahtanum Creek near Tampico

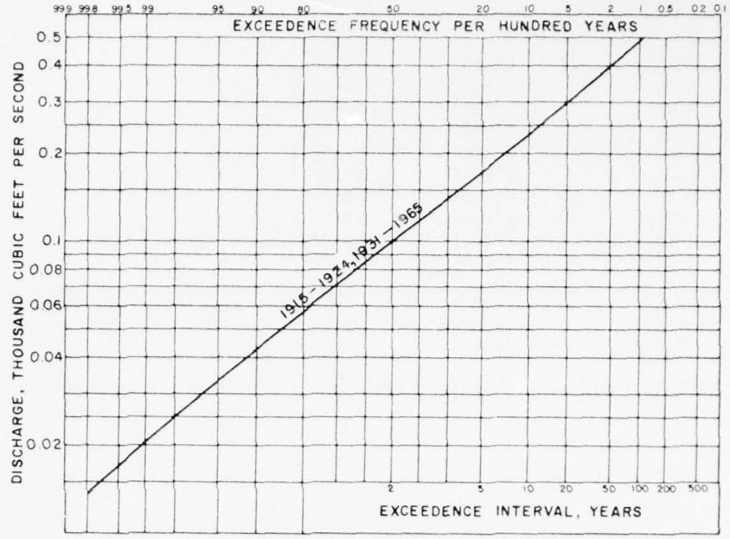


Figure 237 Frequency curve of annual peak flows, S.F. Ahtanum Creek at Conrad Ranch near Tampico

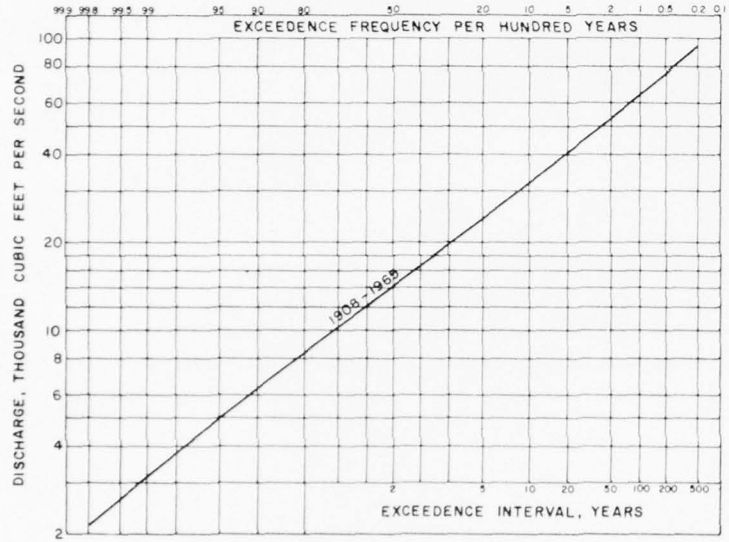


Figure 238 Frequency curve of annual peak flows, Yakima River near Parker

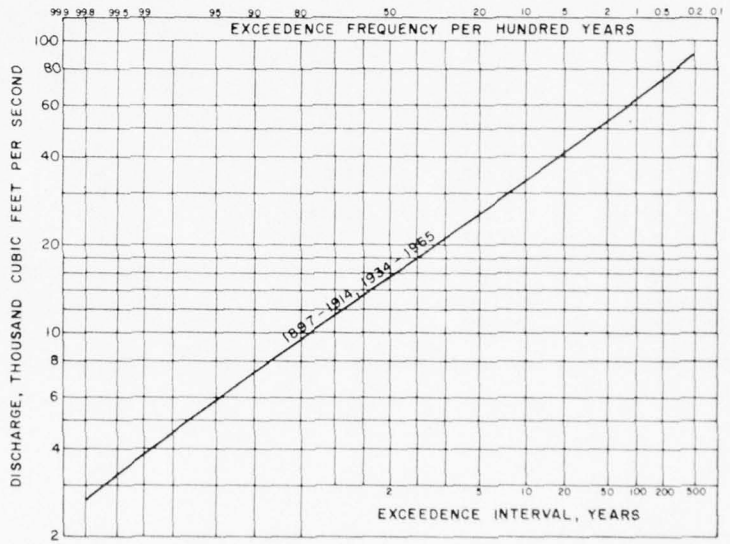


Figure 239 Frequency curve of annual peak flows, Yakima River at Kiona

Table 119. Dependable Yield, Yakima River near Martin, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1942	168.8	51.7
2	1942-43	212.6	65.1
3	1941-43	238.1	72.9
4	1942-45	242.0	74.0
5	1941-45	251.4	76.9
6	1940-45	258.0	78.9
7	1939-45	262.8	80.4
8	1938-45	269.1	82.3
9	1937-45	268.5	82.2
10	1936-45	273.1	83.6
30	1929-58	326.8	100.0

Table 120. Dependable Yield, Kachess River near Easton, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1942	133.9	46.9
2	1942-43	144.2	50.5
3	1942-44	175.6	61.4
4	1942-45	199.7	69.9
5	1942-46	196.9	68.9
6	1942-47	210.3	73.6
7	1941-47	223.0	78.0
8	1940-47	230.9	80.8
9	1938-46	234.8	82.2
10	1937-46	236.6	82.8
30	1929-58	285.8	100.0

Table 121. Dependable Yield, Cle Elum River near Roslyn, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1942	536.6	58.9
2	1942-43	601.7	66.0
3	1941-43	653.5	71.7
4	1942-45	677.8	74.4
5	1941-45	693.7	76.1
6	1940-45	714.8	78.5
7	1939-45	723.3	79.4
8	1939-46	736.5	80.8
9	1937-45	746.1	81.9
10	1937-46	754.4	82.8
30	1929-58	911.1	100.0

Table 122. Dependable Yield, Yakima River at Cle Elum, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1942	878.8	55.8
2	1942-43	1005.8	63.9
3	1941-43	1063.2	67.5
4	1942-45	1090.8	69.3
5	1941-45	1108.2	70.4
6	1940-45	1137.2	72.2
7	1939-45	1165.4	74.0
8	1939-46	1193.3	75.8
9	1937-45	1208.6	76.7
10	1937-46	1226.6	77.9
30	1929-58	1575.0	100.0

Table 123. Dependable Yield, Yakima River at Umtanum, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	1289.8	55.5
2	1930-31	1468.0	63.1
3	1929-31	1506.6	64.8
4	1929-32	1611.8	69.3
5	1941-45	1647.7	70.9
6	1940-45	1666.4	71.7
7	1939-45	1694.7	72.9
8	1939-46	1753.9	75.4
9	1937-45	1795.4	77.2
10	1937-46	1832.6	78.8
30	1929-58	2325.5	100.0

Table 124. Dependable Yield, Bumping River near Nile, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	154.2	53.5
2	1941-42	170.3	59.1
3	1929-31	186.4	64.7
4	1939-42	202.7	70.4
5	1941-45	211.7	73.5
6	1940-45	216.3	75.1
7	1939-45	218.4	75.8
8	1939-46	226.1	78.5
9	1937-45	232.6	80.7
10	1936-45	237.2	82.3
30	1929-58	288.1	100.0

Table 125. Dependable Yield, American River near Nile, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	150.3	63.8
2	1929-30	158.8	67.4
3	1929-31	160.3	68.1
4	1941-44	175.8	74.6
5	1941-45	174.0	73.9
6	1940-45	180.8	76.8
7	1939-45	183.3	77.8
8	1939-46	189.8	80.6
9	1937-45	195.4	83.0
10	1937-46	199.5	84.7
30	1929-58	235.5	100.0

Table 126. Dependable Yield, Tieton River at Tieton Dam near Naches, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1932	278.2	56.2
2	1931-32	306.5	61.9
3	1930-32	357.6	72.3
4	1929-32	371.0	75.0
5	1942-46	367.2	74.2
6	1941-46	377.3	76.3
7	1940-46	382.3	77.3
8	1939-46	384.9	77.8
9	1938-46	405.2	81.9
10	1937-46	402.8	81.4
30	1929-58	494.8	100.0

Table 127. Dependable Yield, Naches River below Tieton River near Naches, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	786.5	53.2
2	1941-42	850.9	57.6
3	1929-31	867.8	58.7
4	1929-32	930.6	63.0
5	1941-45	1028.3	69.6
6	1940-45	1036.2	70.1
7	1939-45	1035.5	70.1
8	1939-46	1069.2	72.3
9	1939-47	1135.7	76.8
10	1937-46	1157.8	78.3
30	1929-58	1477.9	100.0

Table 128. Dependable Yield, N. F. Ahtanum Creek near Tampico, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	28.8	44.4
2	1930-31	36.2	55.9
3	1929-31	37.5	57.9
4	1929-32	41.0	63.3
5	1929-33	45.3	69.9
6	1940-45	46.6	71.9
7	1939-45	45.8	70.7
8	1939-46	46.6	71.9
9	1939-47	49.0	75.6
10	1936-45	50.5	77.9
30	1927-58	64.8	100.0

Table 129. Dependable Yield, S. F. Ahtanum Creek at Conrad Ranch near Tampico, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	7.4	39.8
2	1930-31	9.4	50.5
3	1929-31	9.8	52.7
4	1929-32	10.8	58.1
5	1929-33	12.1	64.5
6	1940-45	13.3	71.5
7	1939-45	13.1	70.4
8	1939-46	13.3	71.5
9	1939-47	14.1	75.8
10	1936-45	14.5	78.0
30	1929-58	18.6	100.0

Table 130. Dependable Yield, Yakima River near Parker, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	356.5	18.8
2	1930-31	467.6	24.7
3	1929-31	473.2	25.0
4	1939-42	728.6	38.5
5	1941-45	891.1	47.1
6	1940-45	869.7	45.9
7	1939-45	854.9	45.1
8	1939-46	941.0	49.7
9	1937-45	1040.8	55.0
10	1937-46	1091.1	57.6
30	1929-58	1893.7	100.0

Table 131. Dependable Yield, Yakima River at Kiona, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	1539.7	47.5
2	1944-45	1769.4	54.6
3	1929-31	1815.8	56.1
4	1939-42	1945.4	60.1
5	1941-45	2087.5	64.4
6	1940-45	2093.4	64.6
7	1939-45	2072.9	64.0
8	1939-46	2165.1	66.8
9	1937-45	2321.8	71.7
10	1937-46	2370.7	73.2
30	1929-58	3239.5	100.0

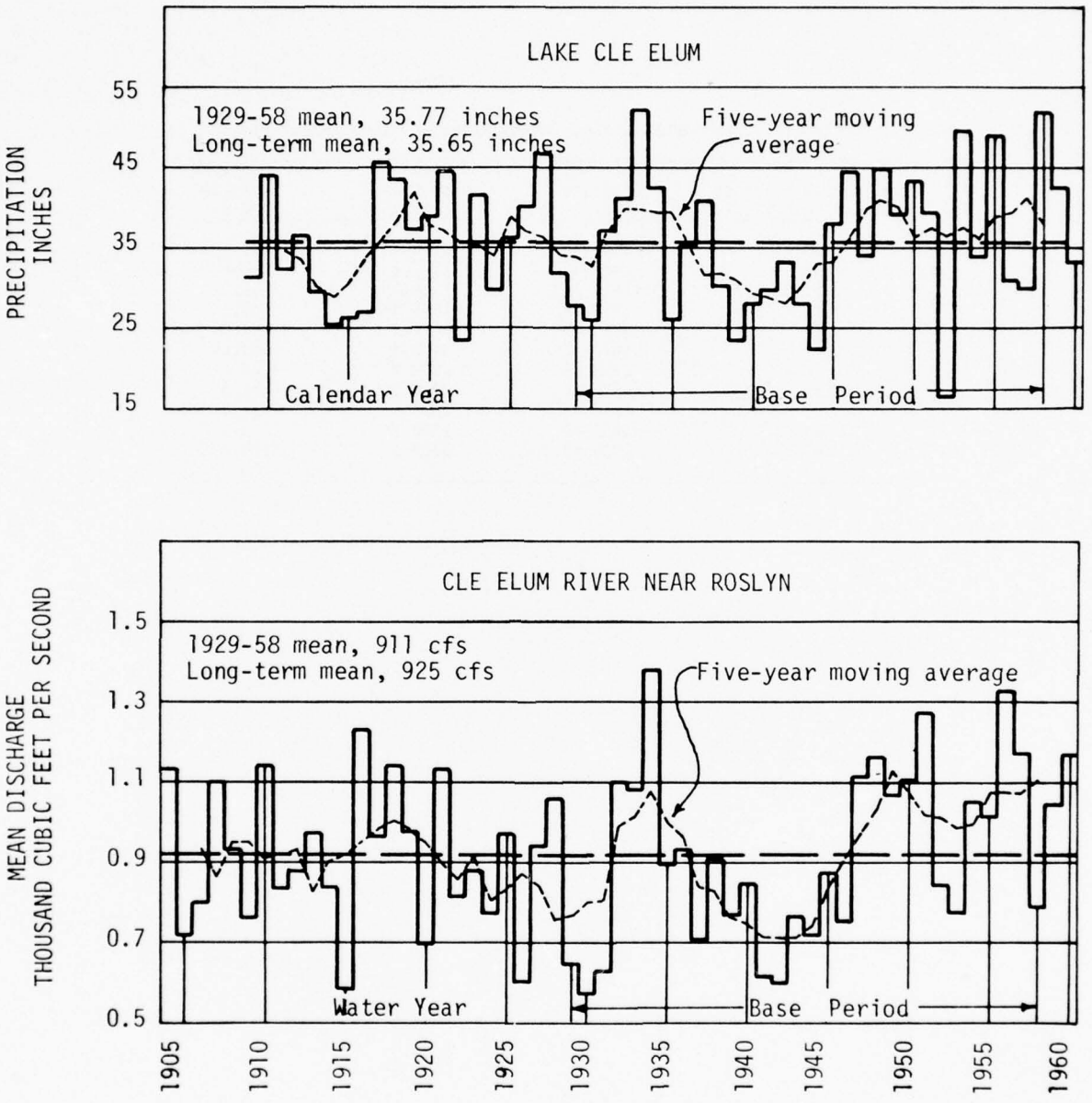


FIGURE 240. Long-term variation in precipitation and streamflow

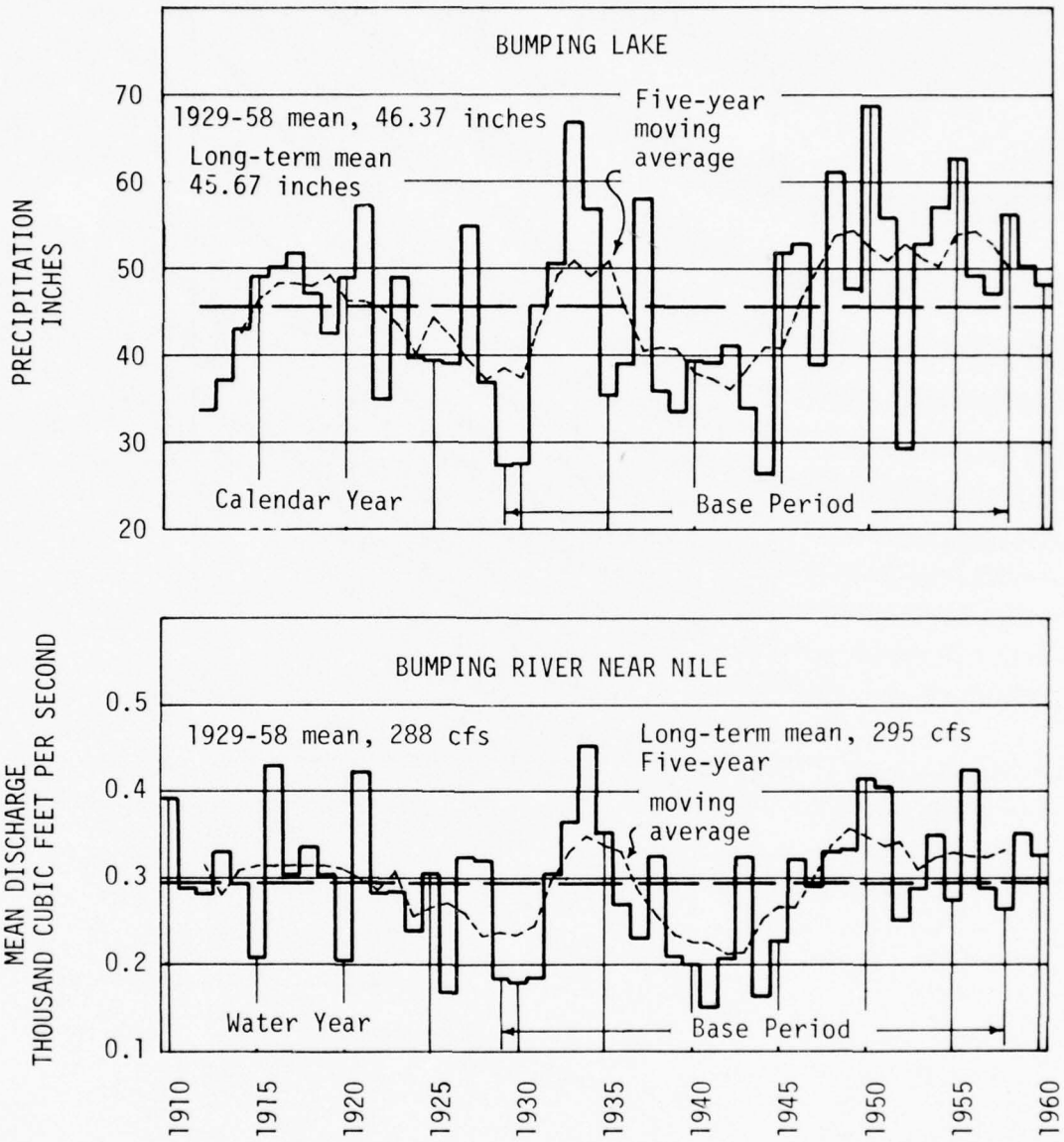


FIGURE 241. Long-term variation in precipitation and streamflow

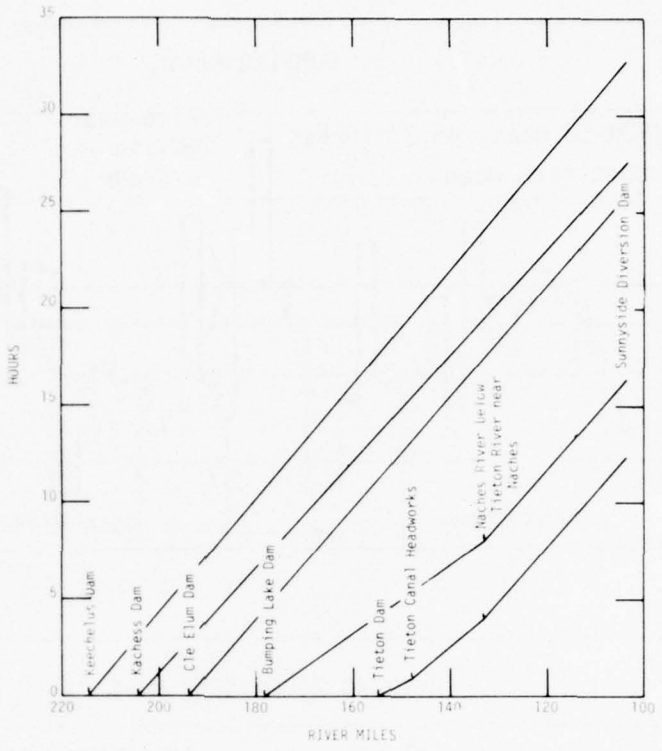


FIGURE 242. Time of travel for releases of 1500 cfs from five reservoirs.

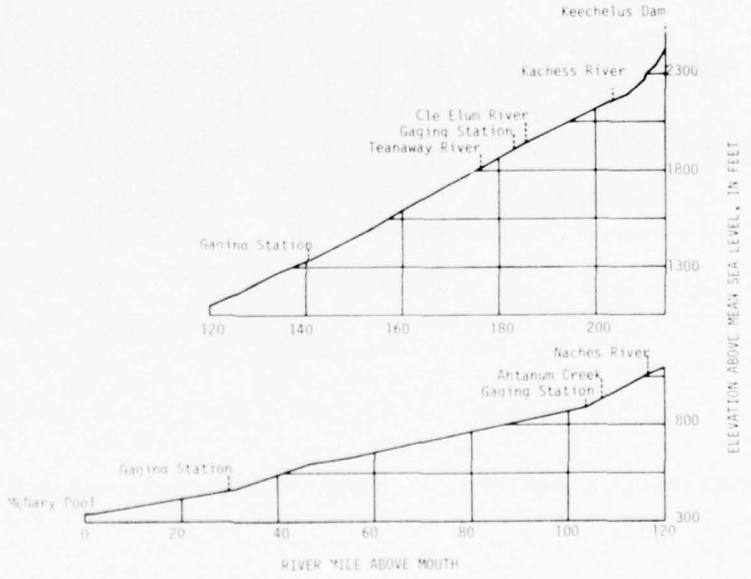


FIGURE 243. Stream Profile, Yakima River

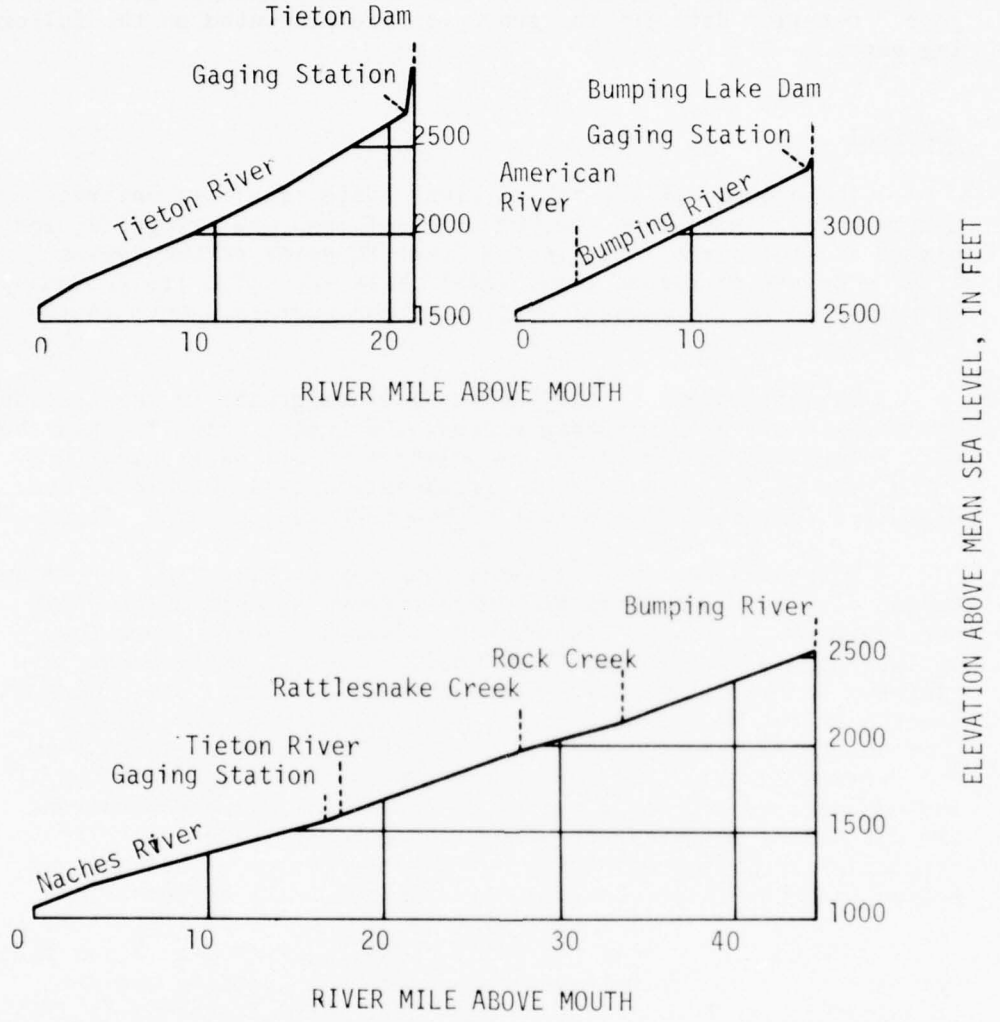


FIGURE 244. Stream Profiles, Naches, Tieton, and Bumping Rivers

Quality

The quality of water in the Yakima Subregion is generally good. Detailed data for the subregion are presented on the following pages.

Chemical

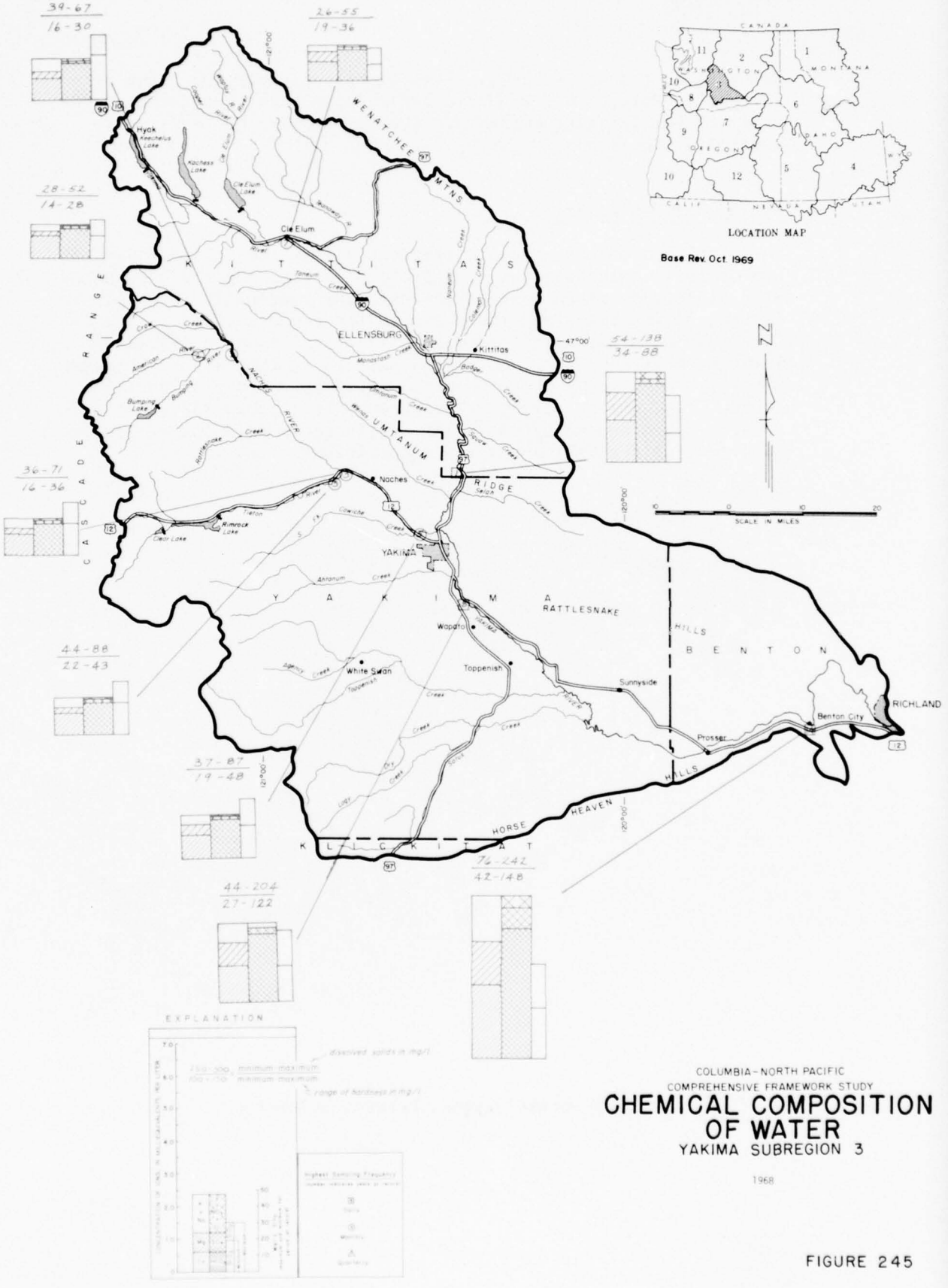
The economy of the Yakima River Basin is almost entirely agricultural. More than 400,000 acres of land are irrigated, and almost all the summer flow in the lower 80 miles of the Yakima River consists of return flow. (155) This intensive irrigation use is reflected in the mineral quality of the surface waters in the basin.

The headwaters of the Yakima River originate in the Cascade Mountains where precipitation exceeds 100 inches annually, and the rock formations are resistant to solution. This environment produces very soft dilute calcium bicarbonate waters which have average dissolved solids concentrations of about 40 mg/l or less (figure 245).

After leaving the mountains, the Yakima River and its tributaries flow for most of their length through an arid basin where precipitation averages less than 10 inches per year. Were there no large-scale irrigation, there would be some natural downstream increase in mineralization and the average dissolved solids concentration at the mouth would probably be about 60 mg/l. (155-87) However, daily records since 1952 for Yakima River at Kiona show the average annual dissolved solids concentration to be 169 mg/l. The maximum and minimum reported dissolved solids concentrations are 242 and 67 mg/l respectively. The water at Kiona is still primarily calcium bicarbonate, but the percentage of sulfate and sodium is about twice that found in the headwater streams.

The mean percentage of salts in the lower Yakima River that were derived from irrigation return flows (by leaching and ion exchange) during the irrigation and nonirrigation seasons in 1959-60 was estimated to be 61 and 49 percent, respectively. (155-89) The high percentage of salts contributed during the nonirrigation season results from the substantial quantity of subsurface drainage which continues to enter the stream as the ground-water table subsides after application of irrigation water ceases.

Even though the mineralization increases over fourfold between the headwaters and the mouth, the waters of the Yakima River are still relatively dilute and only moderately hard. With the exception of high water temperature and its possible effect on the fishery resource, the water quality of the Yakima River has not been seriously affected by irrigation return flows. (155-89) The



COLUMBIA-NORTH PACIFIC
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CHEMICAL COMPOSITION OF WATER

YAKIMA SUBREGION 3

1968

FIGURE 245

water is in the low salinity class and is suitable for reuse as irrigation water. Color and turbidity sometimes exceed the standards set for drinking water, and treatment would be required for control of these parameters.

Biological-Biochemical

Dissolved oxygen concentrations within the Yakima Subregion are normally maintained at satisfactory levels. However, substandard, dissolved oxygen concentrations occur seasonally in local reaches of the river and these are in the process of correction. Data collected during the summer of 1961 and shown in figure 246 indicate that the dissolved oxygen pattern in the main stem Yakima River is governed by photosynthetic organisms, and considerable diurnal fluctuation occurs. The accompanying table 132 gives dissolved oxygen and coliform levels, collected over a longer period of time, for the Yakima and its major tributaries.

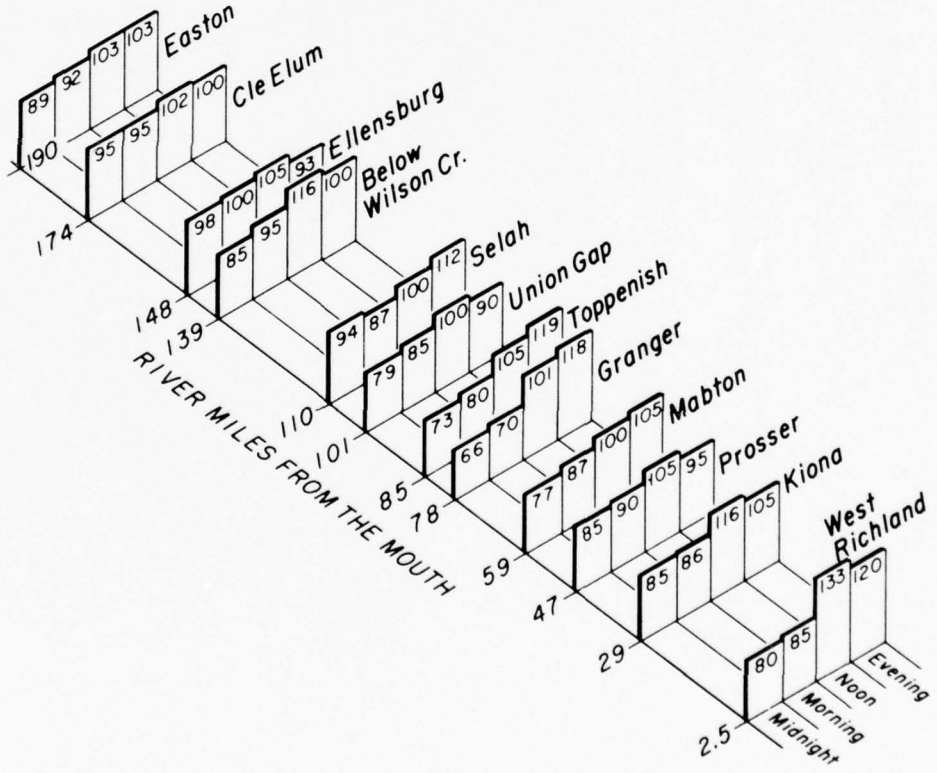


FIGURE 246. Dissolved Oxygen, Percent Saturation.

Table 132. Dissolved Oxygen & Coliform Organisms Densities, Yakima Subregion

Location	Dissolved Oxygen mg/l			Coliform Organisms /100 ml		
	Mean	Min	Max	Mean	Min	Max
Yakima R. at Cle Elum	11.0	8.7	13.5	478	0	9,300
Teanaway R. at Hwy 10 Br.	11.4	8.5	15.1	1,922	0	23,000
Wilson Creek at Hwy 10 Br.	10.0	8.9	11.7	2,346	230	11,000
Middle F. Naches R. nr Cliffdel	12.7	11.3	13.7	36	0	430
Bumping R. at American R.	10.9	8.6	13.5	14	0	91
American R. at American R.	11.5	9.4	14.5	39	0	230
Rattlesnake Creek nr Nile	11.4	8.9	14.5	45	0	430
Tieton R. at Oak Creek	11.3	8.5	14.0	74	0	430
Naches R. nr Naches	12.2	8.4	13.4	4,000	0	24,000
Naches R. nr Yakima	11.9	8.5	16.6	394	0	4,600
Yakima nr Richland	10.5	8.0	15.1	--	--	--

Conversely, coliform densities in the main stem below Ellensburg and on some of the tributaries are above 1,000 organisms/100 ml, indicating a condition unsuitable for swimming or as a raw water supply for municipal and food processing purposes. Figure 247, developed from intensive survey data, illustrates the bacterial quality existing in the main stem Yakima River during the summer of 1962.

Nutrient concentrations in the lower reaches of the Yakima River are in excess of threshold limits for stimulation of nuisance aquatic growths, and heavy growths are found in the river from Roza Diversion Dam to the mouth.

Sediment

Suspended sediment concentration data are almost nonexistent for the Yakima Subregion. A few samples were obtained in 1910-11 at three sites and in 1951-52 (unpublished) at one site. (17) No concentrations higher than 84 mg/l were observed. Sediment data were obtained for five stockpond sedimentation studies in the area generally between Yakima and Ellensburg. The rate of sediment yield in the watersheds contributing to these ponds averaged less than 0.03 acre-foot per square mile. Figure 248 (30) shows that sediment yield in the region ranges between 0.02 and 0.5 acre-foot per square mile per year, but that about 95 percent of the entire subregion produces less than 0.1. The generally low sediment yield may be attributable to either low precipitation and runoff or generally good cover conditions where precipitation is high.

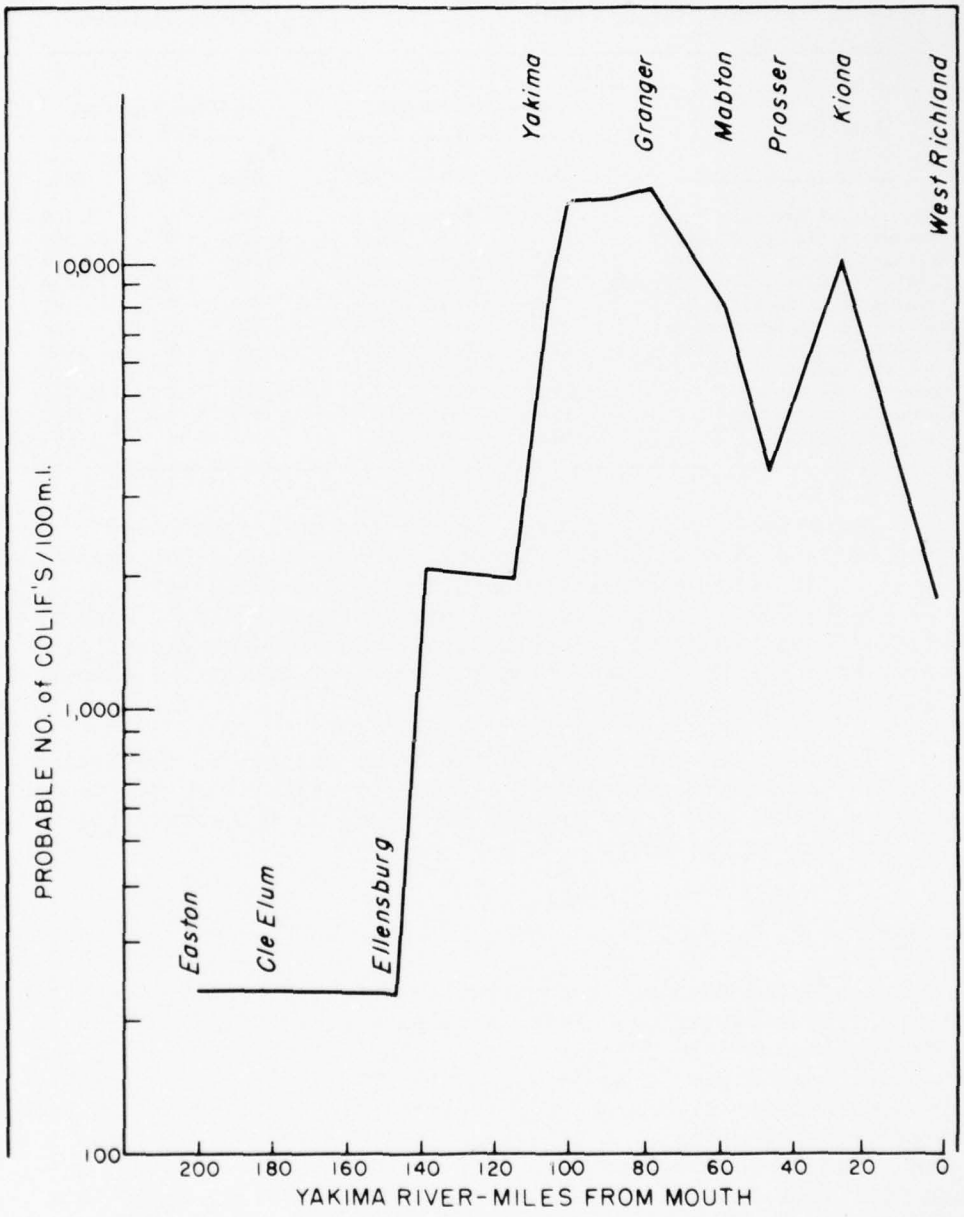


FIGURE 247. Coliform Bacteria Densities.



LOCATION MAP

Base Rev. Oct. 1969

EXPLANATION

Yield in acre-feet per square mile per year

- 0.02 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.5
- 1.5 - 4.0

2,780 Highest observed concentration in mg/l

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERALIZED SEDIMENT YIELD
YAKIMA SUBREGION 3

1968

FIGURE 248

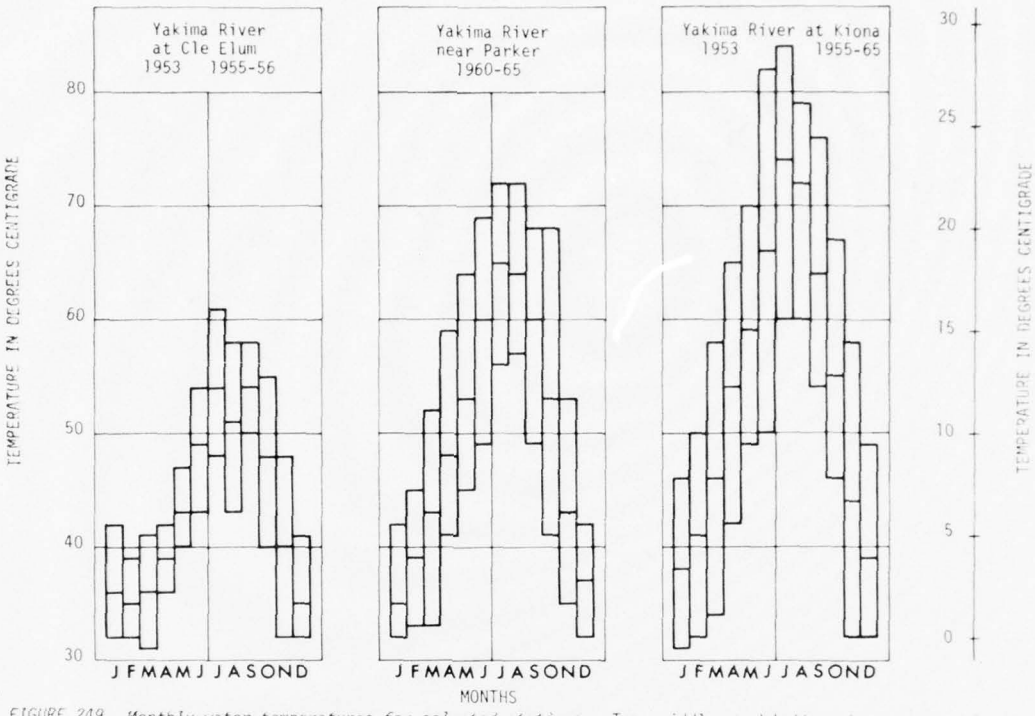


FIGURE 249. Monthly water temperatures for selected stations. Top, middle, and bottoms bars represent maximum, mean, and minimum temperatures.

Water Temperature

Water temperature data are limited in this subregion. Data are collected regularly at only two stations selected for detailed analysis, Yakima River near Parker and Yakima River at Kiona. Limited data are available for the selected station, Yakima River at Cle Elum. The temperature data for these three stations are presented in figure 249. The longer the record, the greater the spread between maximum and minimum water temperatures although the means should be representative of the long-term means. The station Yakima River at Kiona has the longest period of record. The range of the mean July temperature at this station is 70°F. to 78°F. The maximum July water temperature ranged from 75°F. to 84°F. and the minimum from 60°F. to 72°F.

GROUND WATER

There are three important aquifer units in Subregion 3: the alluvial deposits (Qal), the Ellensburg Formation (Te), and the basalt of the Columbia River Group (Tcr). Moderate to moderately large yields can be obtained from wells in any one of the three units at favorable locations, and there has been considerable development and utilization of ground water from each. Large supplies also are available at many other places. The other aquifer units have not been extensively tested but, except for the Tieton andesite which is of small areal extent, probably will yield only small to moderate supplies at most places. The chemical quality of the ground water is generally good to excellent for most uses.

Several reports describe aquifers and ground water occurrence in Subregion 3. These are listed in references 14, 32, 47, 58, 138, 145, and 195.

Aquifer Units and Their Hydrologic Characteristics

Seven aquifer units were delineated in Subregion 3 on the basis of a map compiled by Sceva (58) and the State Geologic Map (54) and are shown in figure 250.

The youngest unit, designated the alluvial aquifer unit (Qal) for brevity, includes chiefly alluvial fan, stream channel, flood plain, and glacial outwash deposits that form valley fills along most of the streams and extensive basin fills in the Ellensburg and the upper and lower Yakima Basins. Some of the deposits have been partly dissected and occur as benches and terraces. The thickness may exceed 500 feet at some places. The materials consist of unconsolidated to moderately well-cemented sand and gravel with lesser amounts of silt and clay. Cemented basaltic gravel underlies benches around the margins of some basins. The stream alluvium and fan material also commonly are basaltic. Gravels that are tightly cemented yield little water, but wells in the unconsolidated or lightly cemented sand and gravel yield several hundred gallons per minute where the zone of saturation is 25 to 50 feet thick. Where 50 to 100 feet of saturated sand and gravel are encountered, yields of 500 to 1,000 gpm generally can be obtained. Specific capacities commonly are 10 to 50 gpm per foot and exceed 100 gpm per foot in some wells.

The Tieton andesite (QTa) of Pleistocene age consists of a series of dark gray to purple, vesicular andesite flows that partly filled the ancestral Tieton and Naches Valleys. Columnar jointing is well developed. It probably has hydrologic characteristics similar to the Tertiary and Quaternary volcanic rocks (QTv) in other subregions and, if so, would be an excellent aquifer where



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

AQUIFER UNITS

YAKIMA SUBREGION 3

1969

FIGURE 250

saturated. It is confined to two small areas, one--a belt about 2 miles wide by 12 miles long between the Naches River and Cowiche Creek, where it may be mostly above the water table--and the other--a small uninhabited area south of Tieton Reservoir. Few data have been compiled for it.

The Ellensburg Formation (Te) is at the surface or underlies the alluvial aquifer unit in most of the Ellensburg and upper and lower Yakima Basins and in the Wenas and Ahtanum Valleys. It consists of massive to thin bedded silt and clay, semiconsolidated sand with minor lenses of gravel or conglomerate. It is predominantly gray-tan or buff with rusty-brown sand and gravel. The materials are chiefly of volcanic origin; the silt and sand consist of ash and pumice with some quartz and dark minerals; the gravel consists of pumice, tuff, and purple andesite. The unit is more than 1,200 feet thick in the Kittitas Valley and may be 1,800 feet thick at some places in the Yakima Valley. The fine-grained and tightly cemented strata have low permeabilities; but lightly cemented, well sorted sand and gravel lenses are moderately permeable. Wells several hundred feet deep at favorable locations commonly yield 100 to 300 gpm, and at a few places 500 to 1,000 gpm. The specific capacities of the better wells generally range from 1 to 10 gpm and rarely exceed 25 gpm per foot.

Basalt of the Columbia River Group (Tcr) crops out over about one-half of the subregion and underlies much of the alluvial aquifer unit and the Ellensburg Formation. The group consists of a great series of flood type basaltic flows 20 to 100 feet thick with some interbeds of sediments and pyroclastics. The basalt is dark gray to black and is fine grained to glassy. The central and basal parts of each flow generally are dense and may be massive or have columnar jointing, but the upper parts generally are vesicular and have platy jointing. Permeable zones occur where a succeeding flow incompletely filled and sealed the porous upper part of the preceding flow. The interflow zones may be very permeable; and where a sequence of several successive basalt flows are penetrated, the chances of obtaining a moderate to large supply of water are good. Interbeds of ash, tuff, or other fine-grained materials reduce the permeability of interflow zones, but coarse-grained sedimentary and pyroclastic rocks increase the permeability of the zones at some places. Where several permeable interflow zones are penetrated, well yields may be 100 to more than 1,000 gpm. Generally, well yields are about one to one and one-half gpm per foot of penetration below the water table. Water may be far below the surface beneath uplands, but at lower elevations some wells flow. Faults and other structures impede the circulation of water in the basalt and may cause water levels that appear to be anomalously high.

The other three aquifer units are largely confined to uninhabited mountainous areas in the western and northwestern parts of the subregion. They include continental sedimentary strata, chiefly of Eocene age (Tc), volcanic rocks of Eocene and Oligocene age (Tov), and undifferentiated rocks of pre-Tertiary age (pT). The sedimentary strata consist of consolidated stratified shale, sandstone, conglomerate, coal, and limestone. Basalt flows, tuffs, and other volcanic rocks are interbedded with the sedimentary strata in some areas. The volcanic rocks (Tov) consist chiefly of andesite and basalt flows with interbedded tuff, agglomerate, and other pyroclastic rocks. The pre-Tertiary rocks (pT) are largely schist, gneiss, slate, and similar metamorphic rocks. Few data are available; but indications are that at most places, rocks of these three units would have small yields sufficient only for domestic or stock use. Coarser grained sedimentary rocks and more permeable parts of the volcanic rocks might yield moderate supplies at a few places. The major importance of these aquifers is their capacity to store significant quantities of water in deeply weathered zones during and after periods of rainfall and snowmelt. Discharge from those shallow ground-water bodies maintains the base flow of streams and is a stabilizing influence on stream discharge throughout the year.

Brief descriptions of the aquifer units, their general hydrologic characteristics, and the general quality of the water yielded by them are given in table 133. The general availability of ground water is shown on a map, figure 251. For maximum utility, that map and the aquifer unit map, figure 250, should be used together.

Because thickness and water bearing characteristics vary from place to place, the yield of wells in any aquifer unit varies greatly. The yield range given applies to the majority of the wells; 5 or 10 percent may yield more, and 5 or 10 percent less, than the range given.

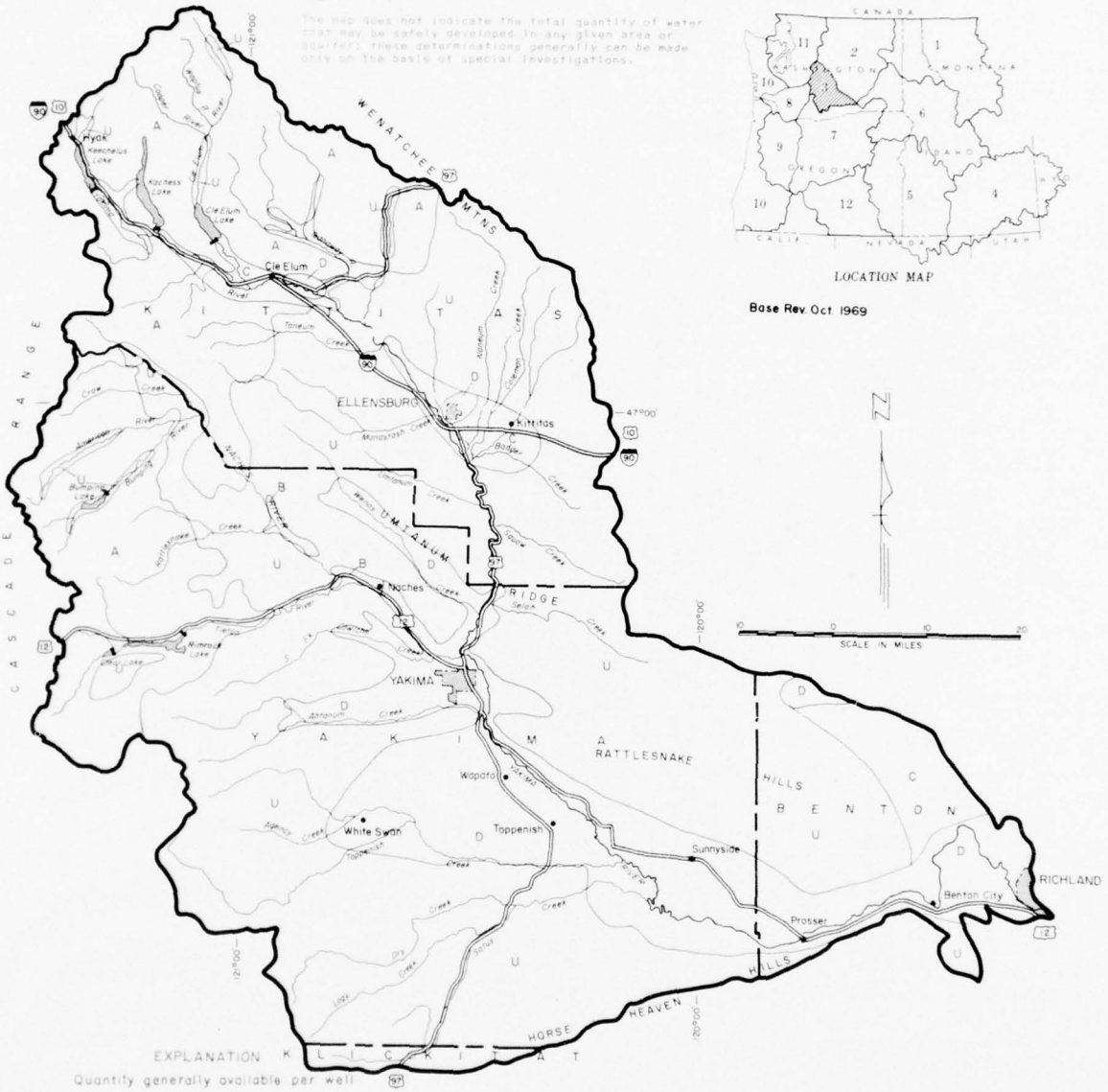
Water in Storage

A rough estimate of the quantity of water stored in a specified depth interval below the water table is given in table 134. The specific yield of the alluvial deposits (Qal) is estimated to be about 20 percent. A specific yield of 5 percent was used for the Tieton andesite (QTa), the value used for volcanic rocks of similar age in Idaho. However, this value may prove to be too high for the Tieton andesite.

The specific yield of the Ellensburg Formation (Te) probably ranges from a few percent to 20 percent. A specific yield of 10 percent was assigned to this unit.

Table 133. Description of Aquifer Units and Their Hydrologic Characteristics, Subregion 3

Map Symbol and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
Qal: Stream channel and floodplain alluvium, including terraces; glacial outwash. Much of material may have been deposited as fans.	Unconsolidated to cemented sand, gravel, with minor amount of silt and clay. Sorting poor to good; the finer-grained deposits are the better sorted.	Tightly cemented gravels yield little water. Wells in unconsolidated or lightly cemented sand and gravel yield moderate to large quantities of water depending upon the saturated thickness.	Dissolved solids generally less than 300 mg/l; total hardness 40 to 150 mg/l. Fluoride, iron low.
QTa: Tieton Andesite of Pleistocene age.	Dark gray to purple vesicular andesite. Columnar jointing well developed.	No records available. Probably similar to younger volcanic rocks (QTv) in other subregions and would be an excellent aquifer.	No data available. Probably similar to water in Qal.
Te: Ellensburg Fm. Upper member, shown on map, is Pliocene age. Lower member interbedded with basalt of the Columbia River Group (Tcr) is not shown.	Massive to thin-bedded, gray, tan, and buff silt and clay with lenses of rusty-brown semiconsolidated sand and gravel or conglomerate.	Unit mostly has low permeability but lightly cemented layers of well-sorted sand and gravel yield moderate to moderately large supplies of water.	Dissolved solids generally less than 300 mg/l. Water moderately hard to hard. Flouride and iron low.
Tcr: Basalt of the Columbia River Group; in Subregion 3 only the upper part, the Yakima Basalt, is exposed.	Commonly dark gray basalt in extensive sheets 20 to 100 feet thick. Center and basal part of flow generally dense and massive or with columnar jointing. Upper part vesicular, platy jointing. Interbeds of sediments and pyroclastics are common.	The lower and central part of each flow has low porosity and permeability. The uppermost few feet of some flows, and the zone between flows at some places are porous and permeable. Where several permeable interflow zones are penetrated, well yields may be 100 to more than 1,000 gpm.	Dissolved solids generally less than 250 mg/l; total hardness chiefly 50 to 100 mg/l. In a few wells the sodium adsorption ratio ranges up to 3.
Tc: Continental sedimentary formations of Tertiary age (chiefly Eocene). Includes Guye, Swauk, Naches, Manatash, Roslyn, and similar formations.	Consolidated, stratified sedimentary rocks, including conglomerate sandstone, shale, coal, and limestone. Naches Fm. includes basalt flows, tuffs, and other volcanic rocks.	Few data available. Small yields probably available at most places. Moderate yields may be available from coarser grained clastic or fractured rocks in favorable locations.	No data available. Probably low in dissolved solids, soft to moderately hard water.
Tov: Older volcanic rocks, chiefly Eocene and Oligocene in age. Includes Teanaway Basalt.	Andesite and basalt lava flows with interbedded tuff, agglomerate, and other pyroclastic rocks.	Rocks are greatly altered and mineralized. Generally low porosity and permeability. Small yields to wells at most places.	No data available. Probably low in dissolved solids; soft to moderately hard water.
pT: Rocks of pre-Tertiary age; chiefly pre-Upper Jurassic age.	Metamorphic rocks including schist, phyllite, slate, gneiss, quartzite, marble, and similar rocks.	Generally low porosity and permeability. Moderately deep weathered zone stores water and provides base flow to streams.	No data available. Probably low in dissolved solids; soft to hard water.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERAL AVAILABILITY OF GROUND WATER
YAKIMA SUBREGION 3

1968

FIGURE 251

Unweathered basalt (Tcr) is very dense in the central parts of each flow, but interflow zones may have a porosity of 5 to 10 percent. The water table generally is below the zone of weathering, and the average specific yield generally is considered to be between 0.5 and 2 percent. A value of 1 percent was used in table 134.

The other three aquifer units, the continental sedimentary strata (Tc), the older volcanic rocks (Tov), and rocks of pre-Tertiary age (pT) crop out on the slopes of the Cascade Range where they have been moderately weathered. A specific yield of 2 percent was assumed for the uppermost 50 feet of saturation which is chiefly in the weathered material.

A storage depth of 100 feet was used for the Ellensburg Formation and the basalt, and 50 feet was used for all other aquifer units. According to table 134, about 13 million acre-feet of water are stored within the specified depth interval in Subregion 3 of which 60 percent is in the alluvial deposits.

About 2 million acre-feet of water are stored in the upper 100 feet of saturated material in each of the Ellensburg Formation and the basalt. However, some of the best aquifers in these units are artesian zones at considerable depth that are more or less isolated from the overlying water table. Large pressure declines in the artesian aquifers can occur with little loss from storage in the unconfined aquifers.

Table 134. Storage, Recharge, and Discharge of Ground Water in Aquifer Units in Subregion 3

Aquifer Unit	Area		Specific Yield	Storage Depth Interval	Water	Annual Natural Recharge and Discharge	
	Sq. Mi.	Acres (1000's)	(Percent)	(ft)	(1000's ac-ft)	Inches Over Area	(1,000's ac-ft)
Qal	1,250	800	20	50	8,000	12	800
QTa	100	64	5	50	160	12	60
Te	325	210	10	100	2,100	4	70
Tcr	3,020	1,930	1	100	1,930	4	650
Tc	460	295	2	50	295	6	150
Tov	730	465	2	50	465	6	230
pT	130	83	2	50	83	6	41
TOTAL (rounded)	6,010				13,000		2,000

Natural Recharge and Discharge

Recharge to the younger volcanic rocks (QTa), continental sedimentary formations (Tc), the older volcanic rocks (Tov), and the pre-Tertiary rocks (pT) that crop out in the wetter, western part of the subregion is from direct precipitation and snowmelt.

Recharge from rainfall is in the autumn and spring and at lower altitudes may sometimes occur in the winter. Recharge is greatest during the spring from the combined effects of rainfall and snowmelt.

The basalt in the Columbia River Group (Tcr) and the Ellensburg Formation is widespread and occurs under a wide range of climatic and topographic conditions. Recharge in the wetter areas probably follows the same pattern as that of the other rock units, except that seepage from streams may be significant at some places. In arid areas the small amount of recharge tc the units probably occurs chiefly during the spring from precipitation, snowmelt, and influent seepage of small streams.

The alluvial deposits are mostly in arid to semiarid areas; recharge from direct precipitation and snowmelt probably is small. Most recharge to the unit probably is from seepage from streams and irrigation diversions. Seepage from streams occurs to some extent throughout the year but is greatest during the spring snowmelt period. In irrigated areas, percolation of irrigation water is by far the largest component of recharge. Hydrographs of a few wells in the alluvial deposits show seasonal rises in the water table ranging from about 2 feet in nonirrigated areas to 20 feet in irrigated areas (figure 252). In addition to the recharge required to raise the water table that amount, some recharge is required merely to maintain the water table at a constant level and some may occur during slow declines in water level. The total average annual recharge to the alluvial deposits is estimated to be equivalent to an annual gross rise in the water table of 5 feet. With a specific yield of 20 percent, this represents an annual recharge of 12 inches over the area of the alluvial deposits. Hydrographs of representative observation wells are shown in figure 252.

Discharge is a continuous process, but the rate of discharge fluctuates with the hydraulic gradient and other factors. Aquifers in the wetter, western part of the subregion discharge water to streams throughout the year, and study of low-flow characteristics of streams in that part of the subregion indicates that effluent ground water probably accounts for 25 to 40 percent of the average discharge of most streams. Estimates of recharge to and discharge from aquifer units in Subregion 3 are based in part on the quantity of the ground water component in streamflow. A rough estimate of the average annual natural discharge is given in table 134. Natural discharge from aquifer units is about 2.0 million acre-feet a year, of which about 1.5 million acre-feet are discharged from the three major aquifers. This figure represents the sum of various components of discharge from the aquifers at many places. Much of the water is intercepted and used before leaving the subregion.

Discharge from the other four aquifer units is about 0.5 million acre-feet a year, nearly as much as is in storage in the specified depth interval. Those aquifers are chiefly in the mountainous, humid parts of Subregion 3. Recharge is frequent; hydraulic gradients are steep; and because of the rugged terrain, points of discharge are close to points of recharge. Under those conditions, most storage is short term.

Annual Ground-Water Withdrawal

Ground-water withdrawal (table 135), based on 1965-67 data and projected to 1970, amounts to about 130,000 acre-feet a year. Practically all the withdrawal is from the three major aquifers (Qal, Te, Tcr). The pumpage amounts to about 6 percent of the natural discharge from aquifers in the subregion.

Chemical Quality of Water

The concentration of dissolved solids in ground water in the subregion generally is less than 300 mg/l. The water is chiefly of the calcium magnesium bicarbonate type and ranges from soft to hard. Fluoride and iron usually are low and there rarely are any other chemical constituents that create hazards or problems. The sodium adsorption ratio ranges up to 3 in water from a few wells in the basalt. Water with the highest concentrations of dissolved solids apparently is from wells in irrigated areas where seepage from irrigated tracts has caused some increased mineralization. Temperatures of water from wells of shallow to moderate depth generally range from 55° to 60°F. Temperatures of water from deeper wells may be considerably higher and the temperature of water from artesian wells in the "Atanum" (Ahtanum)-Moxee Basin ranged from 66° to 80°F. (145-49) Temperatures in artesian wells in the Cold Creek Basin ranged from 68° to 80.5°F. (47-21, table 4)

Chemical analyses for ground water in Subregion 3 are given in several local areal reports (47-21, table 4; 32-59 to 61, tables 5 & 6; 138, table 4) and in a statewide report (175). Wells in the Yakima Valley commonly contain H_2S and other chemical constituents which cause taste and odor problems for domestic water supply.

Present Use and Future Availability

Estimates of present use of ground water are based on data for 1965 to 1967, projected to 1970. Projection of municipal, domestic, and industrial use is based on estimated population growth. Irrigation use was projected on the basis of past rates

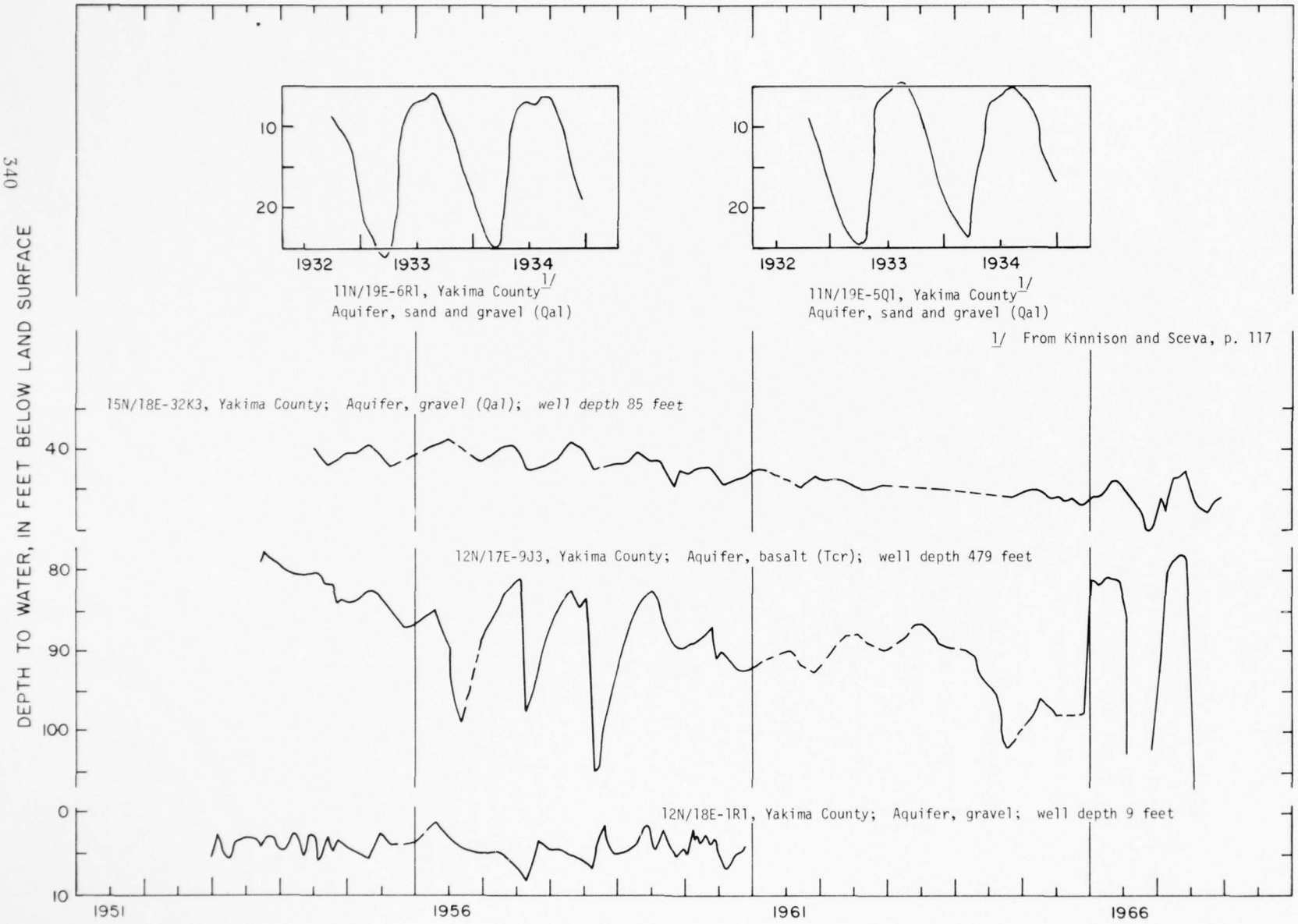


Figure 252 Hydrographs of selected wells in subregion 3

Table 135 - Estimated Ground-Water Withdrawal and Consumptive Use
Subregion 3, 1970

	Ac-ft per year; all quantities in thousands
Irrigation	
Acres irrigated	15
Withdrawal	65
Consumptive use	30
Industrial [1]	
Withdrawal	9
Consumptive use [2]	.5
Public Supplies	
Persons served	90
Withdrawal	38
Consumptive use [3]	7.6
Rural-Domestic	
Persons served	128
Withdrawal [4]	14.3
Consumptive use [5]	7.2
Stock	
Withdrawal and consumptive use [6]	2.4
TOTAL WITHDRAWAL (rounded)	130
TOTAL CONSUMPTIVE USE (rounded)	50

1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

of increase modified for special situations. Ground-water withdrawal and the quantity used consumptively are given in table 135. Because some of the ground water that is withdrawn may return to streams and not return to the aquifers, net withdrawal may exceed consumptive use. However, in most areas where significant quantities of ground water are withdrawn, a large part of the water not used consumptively returns to the ground.

In Subregion 3 annual ground-water withdrawal is about 130,000 acre-feet, consumptive use about 50,000 acre-feet; and net ground-water withdrawal by pumping is a little more than consumptive use, certainly not more than 100,000 acre-feet. A net withdrawal of 100,000 acre-feet annually compared with an annual natural discharge of about 1.5 million acre-feet from the three major aquifers indicates that considerably more ground water could be developed without seriously depleting the supply. However, present development is concentrated in certain areas so that local overdevelopment can occur. Also, part of the surface water supply is dependent on effluent ground water; and although much of the additional withdrawal would be replaced during the rainy winter season, a large increase in pumpage would have some effect on ground-water inflow to streams during the irrigation season.

Artificial Recharge

The only known artificial recharge operation is the local recharge of water in alluvial deposits by the city of Richland. (125-5)

The alluvial deposits readily accept recharge, and recharge to the alluvium might be possible around the peripheries of the various basins where the depth to water may be considerable. Recharge to aquifers in the basalt has been successful on an experimental basis at two places in the region (33, 122), and might be beneficial locally in the Yakima Basin as, for example, in the upper Ahtanum Valley where water levels in the basalt have declined considerably. However, until a larger percentage of the available supply is utilized, large-scale artificial recharge would be mostly wasted effort so far as the ground-water supply is concerned; it might be beneficial to surface water supplies dependent on late season low flows.

Water Rights

In Subregion 3, consisting essentially of Water Resource Inventory Areas 37 through 39 (figure 185), a total of 692 active ground-water right appropriation records in permit and certificate stages were on file with the State of Washington Department of

AD-A036 546 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/8
COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
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Water Resources as of September 30, 1966. Prime rights in this area allow summer period withdrawals totaling 252,380 gpm (555 cfs). Nearly all of this quantity (252,180 gpm) is classified as being consumptive to the resource; the remainder (200 gpm) is partly consumptive. A total of 3,244 gpm has been appropriated under supplemental rights.

Prime water right quantities for the more important use categories and total actual ground-water right quantities are listed in table 136 according to Water Resource Inventory Areas as defined by State of Washington Department of Water Resources. (Regional Summary) More detailed information about specific rights can be obtained from the Department of Water Resources.

Water right filings with the State of Washington generally do not cover wells and ground-water withdrawals on Indian reservations. The Bureau of Indian Affairs lists 54 wells for the irrigation of 9,782 acres on the Yakima Indian Reservation in Subregion 3.

Table 136 - Summary of Ground-Water Rights, Subregion 3, 1966

Basin No.[1]	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total[2]
		(Gallons per Minute)						
37	Lower Yakima	48,801	108,804	39,276	22,939	-	14,730	184,290
38	Naches	9,250	8,315	6,274	5,000	-	1,090	21,454
39	Upper Yakima	10,161	34,638	6,059	1,166	-	4,784	46,636
TOTAL		68,212	151,757	51,609	29,105	-	20,604	252,380

1/ Water Resource Inventory Area number as shown in figure 185.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed and (2) water right quantities that are common to two or more uses are listed under each applicable use category.

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

Streams draining the humid eastern slopes of the Cascade Range receive discharge from the aquifer units underlying those areas throughout the year, and for considerable periods each summer their entire flow is from ground water. Ground water discharges to major streams through most of their reaches; smaller streams draining the mountains at some places lose water by seepage into the alluvium, the basalt, and the Ellensburg Formation where the streams enter basins underlain by those formations. Large volumes of ground water discharge into the Yakima River in the Kittitas Basin and the upper and lower Yakima Basins. The lower reaches of Naches River, Ahtanum Creek, Toppenish Creek, and other streams also receive large volumes of ground-water inflow. Most of this is return flow from surface water diversions for irrigation. Hydrographs in figure 253 show low flow characteristics of selected streams. A moderately detailed description of the relations between surface and ground water is given in the report by Kinnison and Sceva. (58)

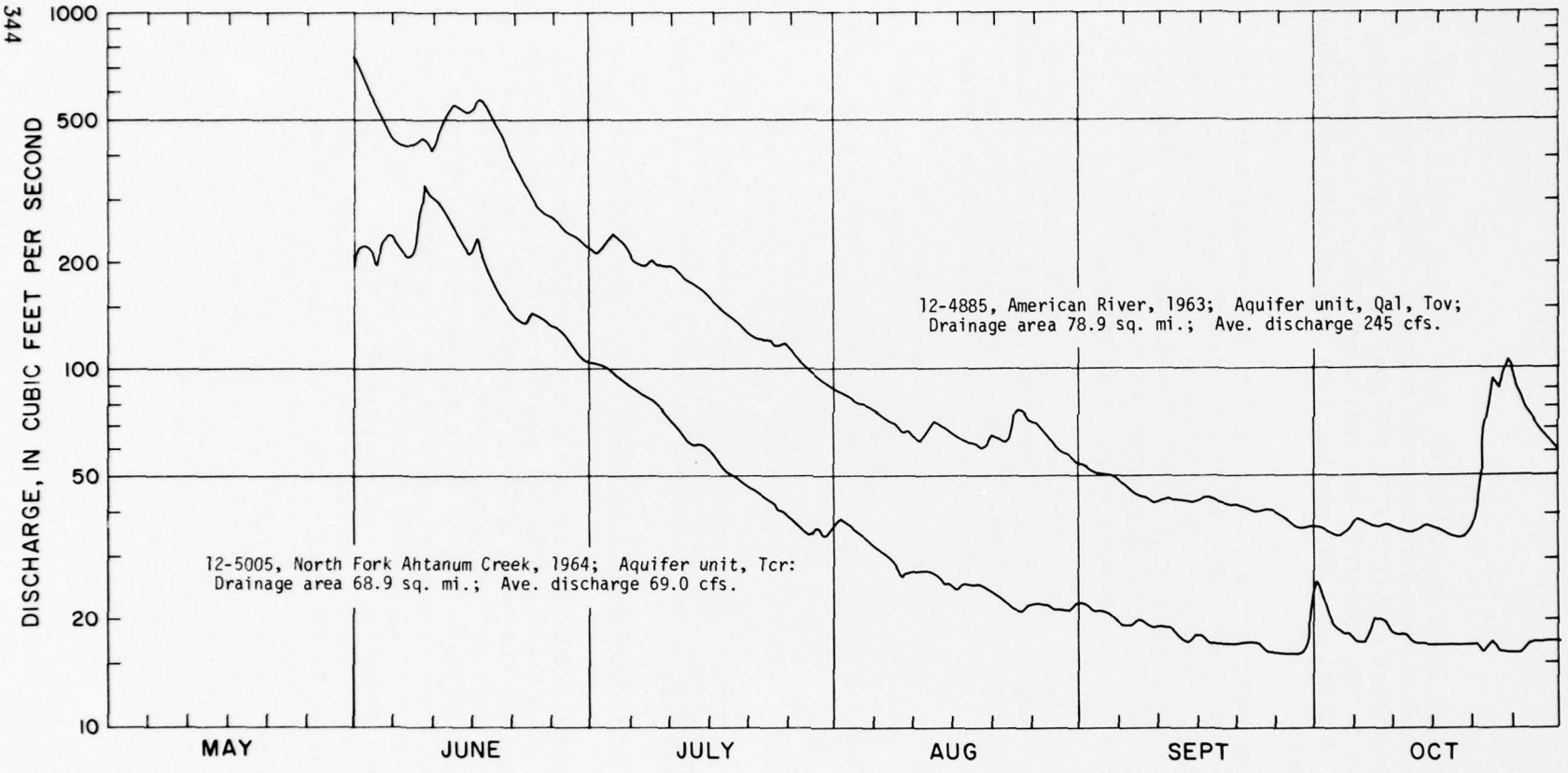


Figure 253 Hydrographs showing low-flow characteristics of selected streams

SUBREGION 4



LOCATION MAP

SUBREGION 4, UPPER SNAKE

HYDROLOGIC FRAMEWORK

The Upper Snake Subregion consists of the Snake River drainage above King Hill, Idaho. This includes the north side areas which contribute to the Snake Plain ground-water aquifer, since these waters reappear as surface flow within the subregion. The area totals 35,857 square miles, with 417 square miles covered by water and 35,440 square miles of land, and is located in the southeastern portion of Idaho and parts of Wyoming, Utah, and Nevada. Figure 1 shows the boundary lines, stream patterns, and other pertinent features of the subregion.

The headwaters of the Snake River originate in Yellowstone National Park at elevations in excess of 9,500 feet. From that area, the river runs south through the Jackson Hole country of western Wyoming, then northwest parallel to a major fault scarp into Idaho. In Wyoming, the river is augmented by inflows from such major tributaries as the Buffalo Fork, Gros Ventre, Hoback, Greys, and Salt Rivers. Upon entering the vast Snake River Valley near Idaho Falls, Idaho, the river is joined by the Henrys Fork and then again turns south and west and begins its crescent-shaped course through the southern part of Idaho. Throughout much of its course in the upper valley, the river approximately parallels the southern edge of lava flows which cover a large part of the Snake River Plain. The average stream gradient between Jackson Lake near the headwaters and King Hill at the lower end of the subregion is about 10 feet per mile; however, there are several falls along its course with the 200-foot Shoshone Falls near Twin Falls, Idaho, being the highest. Below Milner Dam (a few miles east of Twin Falls), the river enters a deep canyon which it has carved through the lava. For this reason, Milner Dam is the last point in Subregion 4 from which substantial surface diversions can be easily made from the Snake River.

The Upper Snake Subregion is largely made up of the extensive Snake River Plain--the upstream half of the Snake River Plateau physiographic province. The Snake River Plain is a broad, level plain well over 50 miles wide in places; it extends some 200 miles from its downstream limit upstream nearly to the Wyoming border. Though large areas of the plain are irrigated, a considerable portion north of the Snake River is dry, sagebrush land with broad areas of exposed lava flows and with scattered volcanic hills and buttes. The plain is bordered on the north and east by the high, rugged mountains of the Northern and Middle Rocky Mountain

physiographic provinces, and on the south by the parallel mountain ranges and broad valleys of the northern extension of the Basin and Range physiographic province.

The principal contribution to streamflow in this subregion is from snowmelt during the spring and early summer months. A major portion of the total flow, therefore, originates in the high mountainous areas where winter snows accumulate to considerable depth. Precipitation is light on the semiarid valley floor and occurs mostly during the winter.

By far the greatest use of water is for irrigation, though water is also used for hydroelectric power generation, municipal, and industrial purposes, and recreation. Irrigation began over one hundred years ago, and has increased until now nearly 2 million acres are irrigated--almost one-third of the irrigated land in the entire Columbia-North Pacific Region.

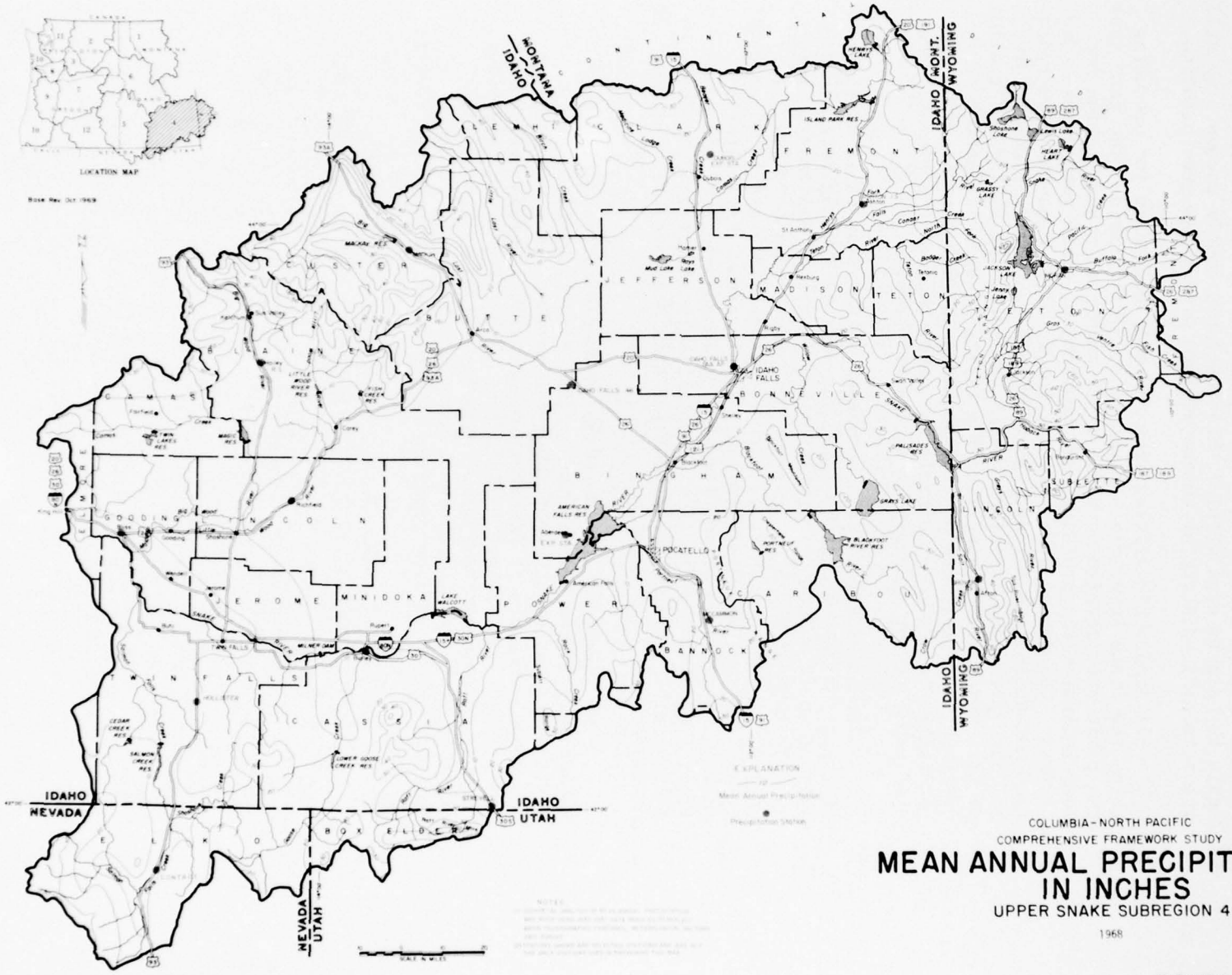
CLIMATE

The climate varies considerably throughout Subregion 4 because of its large size and wide range in elevations. In general the climate is characterized by warm to hot, dry summers and cold winters, during which most of the subregion's precipitation falls.

The following sections present climatic data of the Upper Snake Subregion, including the topics of precipitation, temperature, wind, evaporation, humidity, and sunshine.

Precipitation

Precipitation varies widely with average annual totals in excess of 50 inches in the mountains and less than 8 inches in parts of the Snake River Plain (figure 254). Elevation has an effect on precipitation amounts, but of even greater significance in a particular area is the steepness and direction of slopes. Mountain ranges, over which the moisture-bearing winds must flow, exercise great control over the distribution of precipitation. The windward slopes of such barriers and areas extending several miles upwind generally receive the greatest amounts of rain or snow. Areas in the lee of the mountain ranges have annual precipitation totals that place them in an arid or semiarid classification. The Snake River Plain offers an excellent example of this latter condition. Here the air entering from any direction has already passed over barriers rising to considerable heights



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL PRECIPITATION IN INCHES

UPPER SNAKE SUBREGION 4

1968

FIGURE 254

above the level of the plain, and much moisture has been extracted by this orographic lifting. Not until this air is forced upslope again to heights even greater than those previously encountered will its remaining moisture be condensed into clouds and precipitation.

If orographic lifting were the only mechanism for producing rain, the Snake River Plain might be completely arid. The fact that the plain does receive some 7.5 to 11 inches of precipitation per year indicates the presence, on occasion, of other mechanisms. One of these, the low-pressure system, is of fairly frequent occurrence from autumn to late spring. Another, the convective thunderstorm, is late spring and summer mechanism caused by the rising and cooling of hot, humid air. Thunderstorm activity is also influenced by orographic lifting, and as a consequence the mountainous areas generally receive more rainfall in summer than do the plains. The difference is not as great as in winter, however.

The Snake River Plain northeast of American Falls and much of the highlands of eastern Idaho and western Wyoming receive about half of their annual precipitation from April to September. This is also true of the area near the Utah and Nevada borders, but westward from American Falls the percentages fall off to 30 percent or less in the Twin Falls to Camas County area. Precipitation during the growing season is generally inadequate for crop production. The distribution of precipitation is illustrated by data from several stations throughout the area which have been summarized on table 137.

The important consideration in precipitation during the warmer half of the year is the general air circulation pattern, particularly at some height above the surface. May and June are the months of greatest frequency of so-called "Nevada lows." A low pressure disturbance of this type produces increasingly heavy amounts of rain or snow from around Twin Falls eastward, while often leaving areas to the west untouched by precipitation. In July and August, and on occasion in September, moisture is carried

Table 137. Average Monthly and Annual Precipitation (Inches), Upper Snake Subregion, 1931-60

Station	Elev.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
IDAHO														
Aberdeen Exp. Sta.	4400	.78	.60	.70	.76	.91	.81	.31	.36	.46	.72	.67	.79	7.87
Ashton 1S	5220	1.82	1.77	1.39	1.04	1.45	1.91	.82	.95	.94	1.35	1.56	1.89	16.89
Bliss	3269	1.24	.92	.92	.66	.88	.61	.22	.11	.27	.55	1.05	1.11	8.54
Burley	4180	1.11	.92	.84	.79	.87	.72	.26	.28	.40	.63	.85	.94	8.61
Dubois Exp. Sta.	5462	.89	.79	.69	.79	1.42	1.79	.67	.76	.71	.82	.69	.92	10.94
Hailey Ranger Sta.	5328	2.11	1.88	1.28	1.07	1.33	1.04	.41	.42	.60	.90	1.31	2.18	14.53
Idaho Falls FAA AP	4730	.89	.71	.66	.66	.98	1.13	.46	.50	.63	.63	.62	.80	8.67
Idaho Falls 46W	4933	.73	.77	.62	.51	1.10	1.09	.26	.48	.35	.66	.41	.59	7.57
Mackay R. S.	5897	.81	.68	.56	.62	1.09	1.26	.85	.79	.71	.64	.54	.70	9.25
McCammon 1/	4774	2.03	1.75	1.36	.92	1.55	.98	.54	.65	.65	.86	1.09	1.72	14.10
Richfield	4306	1.41	1.13	.88	.70	.85	.64	.26	.30	.39	.71	1.05	1.32	9.64
Strevell 1/	5275	.66	.64	.82	1.14	1.46	1.14	.75	.93	.66	.87	.78	.65	10.50
NEVADA														
Contact 1/	5365	.95	.54	.70	.64	1.31	.92	.44	.50	.51	.50	.58	.74	8.33
WYOMING														
Grover 2S	6115	1.53	1.51	1.55	1.52	1.95	1.96	1.06	1.05	1.16	1.53	1.52	1.59	17.93
Moran	6798	2.35	2.28	2.08	1.73	1.85	1.77	.97	1.30	1.28	1.45	1.88	2.36	21.30

1/ Period is shorter or longer than the 30-year normal.

northward at higher levels across Nevada and Utah. Typically this moisture current begins to curve northeastward as it approaches Idaho, and again the rainfall is heavier from around Twin Falls eastward than in the valleys of southwestern Idaho.

Total annual snowfall averages nearly 200 inches in the Island Park Reservoir area in the upper end of the subregion, 150 inches at high valley stations in Wyoming, but only about 20 inches in the western part of the subregion. At Teton Pass snow course, west of Jackson, Wyoming, at an elevation of 8,500 feet, the average depth of accumulated snow on April 1 is about 99 inches, with an average water content of nearly 36 inches. Although light snowfall occurs occasionally in September at the higher elevations, few valley areas receive snow until October; and the Snake River Plain does not receive snow until late November or early December. Snow accumulates to a depth of 12 inches or more each year in the upper (eastern) part of the basin, but the probability of this accumulation is less than 1 year out of 4 on the lower Snake River Plain and as low as 1 year in 10 in some localities.

Temperature

Temperatures show a wide range as indicated both by annual averages and extremes. Average annual temperatures range from 35°F. just south of Yellowstone Park to 50°F. at the western edge of the subregion. Temperature extremes recorded over a long period have been 113°F. at Hazelton, Idaho, and -63°F. at Moran, Wyoming. The average number of days per year with maximum temperature 90°F. or higher ranges from less than five at the higher elevations in the eastern section to about 50 at the western limits. The average number of days with minimum 32°F. or lower ranges from 300 at Bondurant, Wyoming, to about 150 at the western end of the area. Minimum temperatures of 0°F. or lower occur on more than 50 days per year in the high valleys, but only about 5 days per year in the lower elevations. Occasionally during winter an arctic air mass will spill over the Continental Divide and cover western Wyoming and eastern Idaho. When skies clear and winds subside in such an air mass, subzero nighttime temperatures are likely, especially over snow-covered surfaces.

The daily range of temperature is large in summer, as shown by the difference between average daily maximum and average daily minimum in July. The range exceeds 45°F. in a few high valleys and is 35°F. or more at nearly all stations on the Snake River Plain. In winter the daily range is considerably smaller, being less than 20°F. in the lower elevations and reaching 30°F. only in the high valleys of the Wood and Lost River drainages. Average and extreme temperature data for several stations are shown on table 138.

Table 138. Average and Extreme Temperatures (°F) Upper Snake Subregion

Station	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
IDAHO														
Aberdeen Exp. Sta.	Av. Max.	30.7	36.8	47.4	60.4	70.3	78.7	89.4	87.0	76.9	63.4	46.5	35.0	60.2
45-yr.	Av. Min.	10.3	16.0	23.4	30.3	37.5	43.8	50.4	47.8	38.9	30.9	21.8	15.0	30.5
	Mean	21.2	26.2	35.5	46.0	54.4	61.6	70.2	67.8	58.7	48.0	34.3	26.5	45.9
	Highest	56	63	73	86	96	103	104	103	97	85	76	67	104
	Lowest	-42	-37	-24	-7	16	22	33	30	9	4	-16	-30	-42
Ashton 1S	Av. Max.	27.9	32.6	39.6	54.0	65.7	73.6	83.3	81.7	72.2	59.2	42.1	30.9	55.2
62-yr.	Av. Min.	8.1	10.8	16.8	28.1	35.3	41.0	45.8	44.0	36.7	29.5	20.3	11.2	27.3
	Mean	18.1	21.7	27.9	41.4	51.7	57.6	64.5	62.5	54.8	45.4	30.3	22.1	41.5
	Highest	54	60	67	88	90	98	100	98	95	85	74	60	100
	Lowest	-35	-37	-30	-3	6	18	24	20	10	0	-18	-36	-37
Burley	Av. Max.	36.4	42.0	50.9	61.3	70.9	79.6	90.8	88.5	78.6	65.8	49.8	40.0	62.9
44-yr.	Av. Min.	16.2	21.3	27.2	34.3	42.0	48.7	56.0	53.2	43.8	34.3	25.6	20.1	35.2
	Mean	26.6	31.5	39.1	48.6	56.9	64.2	73.8	71.4	62.1	51.3	38.0	31.3	49.6
	Highest	62	70	81	89	97	103	106	105	102	91	77	70	106
	Lowest	-35	-27	-7	11	22	27	36	32	16	9	-11	-28	-35
Dubois Exp. Sta.	Av. Max.	25.7	29.2	37.5	54.4	65.3	73.5	85.6	83.7	73.0	58.7	39.6	30.2	54.7
29-yr.	Av. Min.	9.9	12.8	19.2	30.2	39.0	45.2	53.1	51.0	42.8	33.8	21.6	15.0	31.1
	Mean	17.8	21.2	28.4	42.3	52.2	59.4	69.4	67.4	58.0	46.2	30.7	22.6	43.0
	Highest	45	52	70	81	89	95	102	98	95	84	67	54	102
	Lowest	-28	-26	-13	0	18	27	34	32	18	2	-15	-16	-28
Hailey Ranger Sta.	Av. Max.	30.8	35.7	43.0	56.6	67.4	75.5	86.7	84.6	74.4	61.4	43.2	34.0	57.8
55-yr.	Av. Min.	7.5	11.6	18.8	29.1	36.8	42.1	48.7	47.2	39.1	31.3	20.9	10.9	28.7
	Mean	18.7	23.4	30.8	43.3	52.3	58.8	68.0	66.0	57.5	47.0	32.2	23.6	43.5
	Highest	55	62	73	86	93	109	107	104	96	85	73	65	109
	Lowest	-32	-36	-13	-5	19	22	30	24	15	6	-27	-26	-36
Idaho Falls FAA AP	Av. Max.	28.4	34.0	43.8	58.6	68.1	75.4	86.3	84.0	74.4	62.0	44.0	33.6	57.7
29-yr.	Av. Min.	10.1	14.3	22.6	31.8	39.6	45.6	52.1	49.7	41.4	32.6	22.0	15.5	31.4
	Mean	19.3	24.2	33.2	45.2	53.9	60.5	69.2	66.9	58.0	47.3	33.0	24.5	44.6
	Highest	53	59	72	85	91	97	104	99	97	83	72	62	104
	Lowest	-35	-37	-16	1	23	27	37	32	24	13	-15	-19	-37
Mackay R.S.	Av. Max.	29.1	33.5	42.7	56.2	65.4	74.4	85.0	82.8	73.0	60.4	43.4	32.1	56.5
49-yr.	Av. Min.	4.7	9.1	18.5	28.5	36.3	42.5	49.1	46.5	38.8	30.5	19.8	9.7	27.8
	Mean	16.9	21.2	30.0	42.4	51.0	58.1	66.8	64.6	56.3	46.0	30.6	21.6	42.1
	Highest	56	67	68	81	100	100	104	103	98	85	70	57	104
	Lowest	-28	-24	-18	-7	15	21	27	22	15	3	-14	-29	-29
*Strevell	Av. Max.	31.3	35.8	45.4	57.0	66.8	76.2	87.8	85.4	75.6	61.3	43.4	35.2	58.4
19-yrs.	Av. Min.	14.9	18.6	24.3	31.1	38.0	44.5	53.0	51.3	42.9	34.4	24.0	19.0	33.0
	Mean	23.1	27.2	34.9	44.0	52.4	60.3	70.4	68.4	59.3	47.8	33.7	27.1	45.7
	Highest	53	60	70	80	95	102	99	99	95	84	69	58	102
	Lowest	-16	-16	-3	10	17	24	31	30	21	11	-14	-10	-16
WYOMING														
Grover 2S	Av. Max.	27.5	31.9	39.3	50.6	63.0	72.0	81.5	80.1	72.0	59.8	42.6	29.2	54.1
53-yr.	Av. Min.	1.2	4.2	11.0	22.5	31.3	36.0	39.8	37.9	31.2	24.6	15.2	4.2	21.6
	Mean	13.8	17.8	24.8	37.1	47.5	53.3	60.5	58.8	51.7	42.2	27.1	17.2	37.7
	Highest	70	56	69	81	86	96	98	95	92	82	76	60	98
	Lowest	-47	-48	-35	-1	4	20	18	16	1	-5	-30	-55	-55
Moran	Av. Max.	25.3	31.1	37.8	47.7	58.0	67.5	76.9	75.2	66.3	54.1	37.7	28.1	50.5
50-yr.	Av. Min.	-4.5	-1.8	4.7	18.1	28.3	34.5	38.5	36.4	30.4	22.7	11.7	0.8	18.3
	Mean	10.6	14.5	20.9	33.0	43.5	50.9	57.9	55.8	48.3	38.8	26.3	15.4	34.7
	Highest	50	60	62	74	82	92	91	91	87	79	64	53	92
	Lowest	-52	-63	-43	-28	5	18	24	19	7	-11	-28	-50	-63

Note: The mean temperature is for the normal period 1931-60; other data are for the period of record.
* The mean temperature is for the period of record.

The growing season (between the last 32°F. minimum temperature in spring and the first 32°F. in fall) is 135 to 150 days along the Snake River at the lower end of the Snake River Plain and 110 to 130 days at the upper end of the plain. Elsewhere the season varies considerably, being generally less than 100 days at higher elevations, with 32°F. readings likely in all months at elevations above 6,000 feet. For hardier vegetation which can stand temperatures down to 28°F., the season is approximately 25 days longer on the Snake River Plain and nearly 40 days longer at elevations above 6,000 feet.

Wind

Winds at and near the surface are predominantly from south-southwest to west in the Snake River Plain, as indicated by records from airports at Twin Falls, Burley, and Pocatello, and at the National Reactor Testing Station near Arco. Highest average speeds occur in the months of March, April, and May; lowest average speeds occur in July, August, and September. A study by the Bonneville Power Administration indicates that winds of 45 to 50 miles per hour, sustained for a period of 1 minute or longer, can be expected every other year; speeds of around 60 miles per hour 1 year in 10; and speeds of 70 to 80 miles per hour 1 year in 50.

Evaporation

Evaporation from an open pan averages between 40 and 55 inches per year, with 80 percent or more occurring in the period from May through October. Mean annual evaporation from lakes and reservoirs is estimated at 30 to 40 inches.

Potential evapotranspiration ranges from about 19 inches in the cooler portions of the subregion to 25 or 26 inches at the warmer, lower elevations. Actual evapotranspiration is limited by the light precipitation on the Snake River Plain and the water-holding capacity of the soils. Unirrigated soil on the Snake River Plain with water-holding capacity of 2 inches will lose from 7 to 9 inches annually by evapotranspiration.

Humidity

On the Snake River Plain, relative humidity averages 65 to 75 percent in the early morning hours, but decreases to only 25 to 30 percent in late afternoon during the summer. In the winter the average early morning humidity is 80 to 90 percent, and the average afternoon relative humidity is 70 to 80 percent.

Sunshine

The Snake River Plain averages 110 to 120 days of clear skies, 95 to 105 days partly cloudy, and 145 to 155 cloudy days per year, according to limited information on cloudiness in this subregion. Average cloudiness is somewhat higher in the mountainous areas, particularly in summer.

Records at Pocatello indicate that the amount of sunshine which occurs is 65 percent of the total possible sunshine on an annual basis. Monthly values range from 37 percent of possible in January to 84 percent in July. Expressed another way, the average daily sunshine in January is 3-1/2 hours and in July, more than 12-1/2 hours.

SURFACE WATER

The Snake River and its tributaries and those streams along the northern edge of the basin which disappear into the Snake River Plain drain the entire area covered by the subregion. Major surface tributaries include the Buffalo Fork, Gros Ventre, Hoback, Greys, Salt, Henrys Fork, Blackfoot, Portneuf, and Big Wood Rivers. The Henrys Fork and Big Wood Rivers drain areas to the north of the Snake, while the remainder enter from the south or east.

Several streams along the northern edge of the subregion disappear into the ground waters of the Snake Plain, thereby contributing to the spring inflows to Snake River in the Hagerman Valley reach.

Quantity

The discharge of the Snake River measured at King Hill (the lower end of the subregion) represents the total runoff from Subregion 4 after depletion by upstream use. With 1970 level of development, the average discharge from the subregion is estimated at 8,590 cubic feet per second (6,219,000 acre-feet annually). This averages 0.24 cfs per square mile, one of the lowest rates in the region.

Present Utilization

Estimates that were made of the amount of water diverted for use for various purposes during 1965 show an average withdrawal for consumptive uses of 17,600 cfs, with approximately 99 percent withdrawn for irrigation. (115-8) The small remaining withdrawals were

made primarily for municipal supplies and for self-supplied industrial uses. Actual consumption of water was estimated to be 5,760 cfs. Comparing the total withdrawal of 17,600 cfs to the estimated natural discharge within the subregion of 13,440 cfs, (115) suggests to some extent the amount of return flow and subsequent reuse of water in the area. In addition, much of this water was used several times for a moderate amount of hydroelectric power generation.

Other nonconsumptive uses of water are: (1) navigation of the rivers by pleasure craft; (2) use of most streams, lakes, and reservoirs for fishing, boating, and other water sports; and (3) dilution and transport of waste materials from municipal and industrial sources along many of the rivers.

Stream Management

Management of streamflow within the subregion is performed primarily to provide water to various users and to prevent damage from flooding. The fact that shortages of water exist during dry years illustrates the need for effective distribution among the different priorities of use. Supervision over the distribution of water along the main stem of the Snake River above Milner Dam and of the Henrys Fork is the responsibility of the watermaster of Idaho Water District 36. Watermasters on tributary streams, all of whom are elected officers of the respective districts, have similar responsibility in their separate areas.

Impoundments Table 139 lists 25 reservoirs in Subregion 4 having capacities greater than 5,000 acre-feet. Nine of these are located on the main stem of the Snake River above Milner Dam or in the Henrys Fork Basin and are integrated into a system operation. Two others (Murtaugh Lake and Wilson Lake) are offstream reregulation reservoirs which also serve this system, but the remainder are on tributaries where their use is local.

Power is generated from the releases at four of the reservoirs listed in table 139 and at several run-of-the-river powerplants. The amount of streamflow regulation for power production, however, is small compared to the regulation for irrigation.

In general, a reservoir operation pattern is followed of storing excess natural streamflow during the winter and spring months, then releasing storage to augment natural flows during the summer irrigation season. There are variations from the pattern at some reservoirs because of flood control operations which may

delay reservoir filling; however, by the use of streamflow forecasts, the system can still be operated to maximize summer yields for irrigation.

Diversions The major water diversions in Subregion 4 are made for irrigation, with minor diversions for municipal and industrial uses. Extensive irrigation diversions are made in Idaho along the Snake River and all its tributaries, and substantial though much smaller areas are irrigated in Wyoming in Jackson Hole and along the Salt River. Only minor acreages are irrigated along the Snake River's tributaries in the small portions of Utah and Nevada which are within the subregion.

Channel Modification Permanent levees, dikes, and improved flood channels have been constructed along some reaches within the subregion to provide local protection from flooding and channel change. At other locations, emergency work is performed during floods, but this work has minor permanent effects.

Along the Snake River in the Jackson Hole area in Wyoming, and again between Heise and Roberts, Idaho, levees have been constructed which protect adjacent land from flood discharges. Levees along the Blackfoot River, together with a downstream flood relief or overflow channel, provide protection for the town of Blackfoot and adjacent farmland. Local levees provide protection to isolated improvements and small communities along the upstream reaches of the Portneuf River, while, through the city of Pocatello, the Portneuf flows in a concrete-lined channel with a 6,000 cfs capacity. Levees along the Little Wood River protect the town of Carey, and a floodway alleviates flood problems for the more frequent flows at Gooding. At other locations, some channel clearing has been accomplished to reduce the accumulation of debris and ice during high flows.

Forecasting Forecasts of expected runoff are used for various purposes in this area. Probably the most important use is for scheduling the storage of water in major reservoirs. Where formal flood control agreements have been made, the forecast of remaining seasonal runoff determines the amount of space that should be available for storage and control of possible flood discharges. Since this same space is also used for irrigation storage, a prime

Table 139 - Reservoirs With a Capacity Greater Than 5,000 Acre-Feet, Subregion 4

Name	Stream	Total Storage (ac-ft)	Active Storage (ac-ft)	Surface Area (acres)	Purpose[3]
American Falls	Snake R.	1,700,000	1,700,000	56,600	IP
Blackfoot R. (Blackfoot-Marsh Reservoir)	Blackfoot R.	413,000	350,000	17,300	I
Cedar Cr.	Cedar Cr.	29,930	28,200	-	I
Fish Cr.	Fish Cr.	13,500	13,500	558	I
Grays Lake	Willow Cr.	100,000[1]	40,000	22,000	I
Grassy Lake	Grassy Lake	15,450	15,180	310	I
Henrys Lake	Henrys Fork	83,200[1]	79,400	6,356	I
Island Park	Henrys Fork	127,600	127,200	7,794	I
Jackson Lake	Snake R.	847,000	847,000	25,540	FI
Lake Walcott	Snake R.	210,000[2]	95,000[2]	11,700	IP
Little Wood R.	Little Wood R.	30,000	30,000	571	CFIR
Lower Salmon	Snake R.	18,800	5,600	840[1]	P
Mackay	Big Lost R.	44,500	44,350	1,360	I
Magic	Big Wood R.	192,000	191,500	3,904	I
Milner Lake	Snake R.	28,200	22,000	3,020	I
Mud Lake	Camas & Beaver Creeks	61,660	60,000[1]	6,600	I
Murtaugh Lake (Dry Cr. Res.)	Snake R. (offstream)	12,000	3,000	-	I
Oakley (Goose Cr. Res.)	Goose Cr.	74,350	74,350	1,250	I
Palisades	Snake R.	1,402,000	1,200,000	16,240	CFIMPR
Portneuf-Marsh Valley	Portneuf R.	23,695	-	1,593	I
Ririe[4]	Willow Cr.	100,000	90,000	1,560	CFIR
Salmon Falls Cr.	Salmon Falls Cr.	228,000	182,700	3,400	I
Teton[4]	Teton R.	315,000	200,000	2,250	I
Twin Lakes	McKinney Cr.	31,240	-	4,040	I
Wilson Lake	Snake R. (offstream)	-	18,500	1,432	I

1/ Estimated.
2/ Under normal operation.
3/ M-municipal, P-power, F-flood control, R-recreation, I-irrigation, C-fish and wildlife conservation.
4/ Under construction.

consideration is to operate the reservoirs during the peak runoff period in such a manner that the storage space will be full when the flood threats have passed.

On the Portneuf River and a few other tributaries, forecasts of impending high flows from rain or rapid snowmelt help the residents prepare for flood conditions. Also, in those areas where carryover of stored water is not available, the forecasts of seasonal runoff volumes assist the irrigators in planning for use of a limited water supply.

Constraints Interstate compacts, minimum flow demands, and the priority use of water all play an important role in determining regulation of streams in this subregion. Controversy over the distribution of Snake River water originating in Wyoming, but used mainly in Idaho, led to the Snake River Compact between the two states in 1949. Distribution between existing irrigators was specified, with a provision included for future development in both states.

There is also a contract in effect to provide for specified minimum discharges in the Snake River below Milner Dam; these discharges are for power generation at downstream plants.

Water Rights

Within the limitations of the Snake River Compact between Idaho and Wyoming, individual rights to the diversion of natural flow on the main stem of the Snake River and its tributaries are on a priority basis and have been established through numerous court decrees or through permits according to state law. Depending upon the states involved, these rights are given priority according to the date of the original filing or use, with the earliest priority dating back to 1880. Storage allocations are made to individual irrigators or reservoir owners each year, according to the amount of space owned in the different reservoirs and the available stored water in these reservoirs.

Idaho A majority of the rights to the use of water from the main stem of the Snake River in Idaho from the Wyoming line to Milner Dam have been adjudicated. Most of these rights are for irrigation use, with a few for power purposes. There are also a number of unadjudicated permit rights and use rights.

Because of late-season irrigation water shortages, reservoirs with large storage capacities have been developed within the

subregion. Sufficient storage capacity is now available to control the Snake River so that no excess flows would pass Milner Dam (the last major surface-diversion point in the subregion) in a period of low runoff such as 1931-38. The small releases past Milner Dam during such years are in fulfillment of contractual agreements with downstream power producers and are not subject to appropriation. However, during years of high runoff there is still much water available. Economical development of this water will require construction of additional storage facilities. Figure 255 illustrates the general amounts and occurrence of discharges at Milner Dam which could be utilized in future basin development.

Downstream from Milner Dam in Subregion 4, rights are generally unadjudicated but are recognized by permits and licenses. Water is used mainly for hydropower purposes, and the power permits in most instances were granted upon the condition that such use would not interfere with future upstream depletions of the water supply.

Rights to water used for irrigation from Henrys Fork, the Teton River, and other tributaries in the same area have been adjudicated. Not all of the water in these tributary streams is available for use within the area, however, because of prior rights to storage and use downstream on the Snake River. Only during periods when excess water is being released past Milner Dam can any future appropriation be made on local streams except through exchange agreements with downstream users.

There has been some recent development as a result of pumping water for sprinkler irrigation of benchlands formerly dryfarmed. Such use has been through direct or exchange use of storage water or through early season irrigation with floodwaters developed under permits.

The major use of water on Willow Creek, Blackfoot and Portneuf Rivers is irrigation, for which the rights have been adjudicated. There is a major wildlife development at Greys Lake for which there are storage permits which have not been adjudicated.

Flood discharges on Willow Creek will, in the future, be impounded behind Ririe Dam (under construction) and used for irrigation. With this storage, there would be only 11 months in a study period of 432 months when releases from Ririe would be made in excess of proposed use.

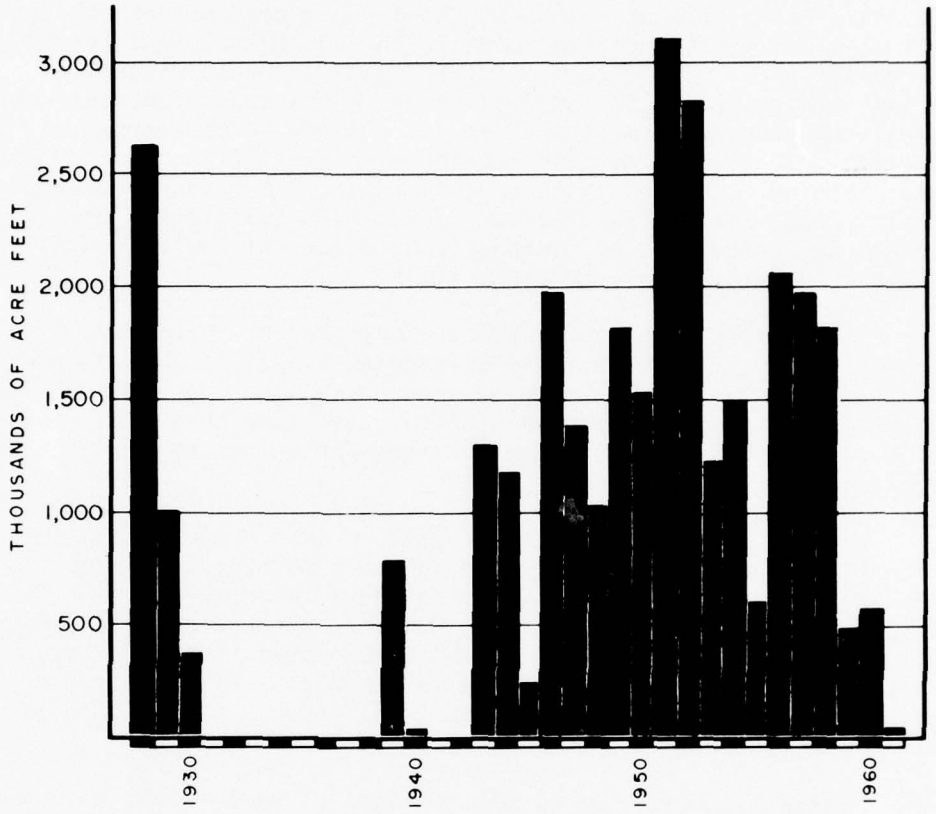


FIGURE 255. Uncommitted Water Passing Milner Dam.

The Portneuf and Blackfoot Rivers also are subject to periodic high flows, but the floodwaters are not entirely available for appropriation since they flow into American Falls Reservoir where prior rights exist. Further development on these streams may be possible only through new storage or water exchanges.

Upper Snake River southside tributaries are generally fully appropriated except for extreme floodflows and except in their lowest reaches where irrigation return water increases the natural flow. Irrigation is the primary use, and many of the rights have been adjudicated. In general, the base flow of streams has been appropriated. Future development will likely be limited to construction of storage reservoirs to control the extreme fluctuations of many of the streams.

The primary use of water from Upper Snake Subregion northside tributaries is for irrigation. The rights have mostly been adjudicated, but there are still many uses under permits and licenses. East of the Little Wood River the streams do not flow into the Snake River, but occasionally discharge large quantities of water to the Snake Plain aquifer. Only on Camas Creek is there storage at the lower end of the drainage area (in Mud Lake). Future development may therefore be possible on some of these streams through construction of additional storage. The base flow of all the northern tributary and nontributary streams of the Upper Snake Subregion appears to be appropriated under present conditions.

Nevada On March 3, 1923, the Fourth Judicial District of the State of Nevada adjudicated all vested rights on the Salmon River and tributaries in Nevada and provided for 40,338 acre-feet of water appurtenant to 13,433 acres of land. Of this quantity of water, 12,500 acre-feet was for the Vineyard Land and Stock Company. In 1947, the Salmon River Canal Company Limited of Idaho acquired a part of the Vineyard Land and Stock Company property in Nevada, along with appurtenant water rights, and, in 1949, filed application with the Nevada State Engineer to transfer these water rights to property in Idaho. This application was protested and resulted in the Salmon River Agreement, dated October 6, 1952, between the Salmon River Canal Company of Idaho and the Nevada users which had the effect of settling the water rights issue on the Salmon River.

Table 140 - Existing Nevada Surface Water Rights, Subregion 4, 1969

Status	Mining	Municipal	Other	Reservoir Storage Rights
	(Cubic Feet per Second)			(Acre-Feet)
Certificates				11,200
Permits				16,420
Applications	3	2	2	4,200

Goose Creek heads in Nevada but its waters are impounded in Goose Creek Reservoir in Idaho and they are used principally for irrigation in Idaho. The adjudication of Goose Creek and Little Goose Creek decreed a total of 3,826 acre-feet of water for 996 acres of irrigated lands in Nevada.

Utah Water rights in tributaries to the Snake River which arise in Utah have been adjudicated and are tabulated in the Proposed Determination of Water Rights in Box Elder County by the State Engineer of Utah. They include Goose Creek, Raft River, Clear, George, and Johnson Creeks.

The most significant use of water in this area is that used for cropland irrigation. Water rights for this purpose amount to about 27,500 acre-feet per year to be used on about 9,300 acres. Most of the other water rights are for domestic and stockwater use. The primary rights have priorities dating back to the early 1880's with the earliest being 1878.

Storage in the area is very limited, consisting of only one reservoir with a capacity of about 750 acre-feet. Water shortages in July and August are common because of lack of storage facilities and consequently most water rights are not fully satisfied. There is opportunity for creating some additional storage which would stabilize the water available for use.

Wyoming Existing water rights for the Wyoming portion of the upper Snake River Basin are primarily irrigation rights, although permits are existent for domestic, municipal, industrial, and power uses concentrated in the Salt River Valley and the Jackson Hole area. Most of these rights are adjudicated, but there are a significant number of unadjudicated permits in good standing. Table 140A shows the rights in good standing through 1963. It should be noted that, while these figures do not necessarily represent the actual acreage irrigated each year, they do show the rights which have a valid claim to water under Wyoming law.

Historically, many portions of the basin suffer from late-season water shortages as most of the runoff occurs during May, June, and July. This problem is acute in the Salt River and upper Teton areas and could be alleviated by additional storage. At the present, there are very few storage facilities to supplement the supply for the junior appropriators in the latter part of the irrigation season. However, at this time suitable storage sites which can be economically developed are in short supply.

In general, it is concluded that the potential for further irrigation development in the Wyoming portion of the upper Snake River Basin is limited. Development in the Salt River and upper Teton drainages is nearing the limits practicable under present irrigation practices, and the limitations of the Snake River Compact and the Roxana Court Decree. However, the recent trend toward the use of sprinkler systems in these two areas has lowered diversion requirements to some extent making some water available for new appropriations. Additional storage and the additional improvement

Table 140A - Existing Wyoming Surface Water Rights, Upper Snake Subregion, 1963

Unit	Irrigation	Other	Reservoir Storage Rights
	(Cubic Feet per Second)		(Acre-Feet)
a			
Snake River	954	364	3,344[1/]
Hoback River	103	2	
Salt River	1,024	791	675
Greys River	9		
West Teton	103	23	[2/]
TOTAL	2,193	1,180	4,019

1/ Excluding 838,000 acre-feet of storage in Jackson Lake for irrigation of lands in Idaho.

2/ Excluding 201 acre-feet--Permit No. 6001R. Bergman Lake Reservoir; 904 acre-feet--Permit No. 6000R. Indian Lake Reservoir; and 15,204 acre-feet--Permit No. 463IR. Grassy Lake Reservoir--water used for Idaho lands.

of irrigation systems to more efficiently utilize the available water supply could result in additional water being made available for future development in these two areas.

The controlling factor in the future irrigation development of the Snake River Basin in Wyoming is the limited amount of privately owned land available for irrigation. Increasing recreational and tourist development in this drainage is resulting in rising land values and a withdrawal of private land from irrigation for other uses.

Discharge

The base period used in this study is October 1928 to September 1958 (water years 1929-58). The validity of using this 30-year period to represent average conditions in the upper Snake River Basin can be seen from figure 298 which shows that the base period average discharge equals 95 percent of the longer 56-year record. Except as otherwise indicated on a few of the tables and figures, all data used have been modified to reflect stream development and use as of 1970.

Measurement Facilities The 11 sites at which runoff data are shown in this report are considered representative of the various drainages and conditions existing in the subregion.

Locations of the selected sites are shown on figure 256, a map of mean annual runoff for the subregion, and are identified by Geological Survey Station numbers. A summary of runoff data and other information for each station is listed on table 141. Momentary flows shown in the table are observed extremes for the entire period of record for each station. In most cases the extremes have been affected by upstream regulation.

Average Discharge for Subregion 4 Figure 256 is a map of isopleths showing mean annual runoff for the subregion. Figure 257 presents graphically the monthly discharge data for the Snake River at King Hill, Idaho, based on 1970 development. Water passing this station is the total outflow from the Upper Snake Subregion. A listing of these same data is shown on table 142.

Table 141. Streamflow Summary for Selected Sites, Subregion 4

Stream	Station	Station No.	Gage Datum	Drainage Area (Sq. Mi.)	Period of Record	Mean Annual Flow 1/ (cfs) Mean	Max.	Min.	Momentary 2/ Flow (cfs) Max.	Min.
Snake River	Moran	110	6727.84	824	04-65	1362	2030	995	15,100	2
Snake River	Ida.-Wyo. line	235	5543.89	3,940	45-54	4780	7075	2980	28,200	1050
Snake River	Heise	375	5015.3	5,752	11-65	6489	8735	4/65	60,0003/	460
Henrys Fork	Rexburg	565	4807.03	2,920	09-65	1512	2387	798	11,000	183
Blackfoot River	Blackfoot	685	4420	1,295	13-65	154	294	41	1,710	0
Portneuf River	Pocatello	755	4436.98	1,250	11-65	236	383	118	2,990	0.4
Snake River	Neeley	770	4241.6	13,600	06-65	6271	9241	4545	48,400	50
Snake River	Milner	880	4062.9	17,180	09-65	1545	4583	244	40,000	2
Big Lost River	Mackay	1270	5946.39	813	19-65	279	418	128	2,990	18
Big Wood River	Gooding	1525	3345	2,990	16-65	198	688	21	8,860	0
Snake River	King Hill	1545	2492.3	35,800	09-65	8590	11999	6909	47,200	1250

1/ Regulated values for base period (water years 1929-58), with estimated 1970 conditions of development.
2/ Observed values for period of record.
3/ Result of washing out of landslide on Gros Ventre River.

Table 142. Discharge in Upper Snake Subregion, 1929-58
(Mean Discharge, in CFS)

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Maximum Months												
12,074	12,024	12,108	12,373	17,693	15,432	22,039	13,765	10,971	7,973	8,183	8,529	12,720
20 Percent												
10,885	10,555	10,205	11,389	11,602	14,103	16,834	10,172	7,507	7,523	7,946	8,276	10,572
Mean												
8,814	8,418	8,458	8,922	9,593	10,471	10,498	7,987	7,320	7,227	7,545	7,904	8,590
80 Percent												
7,793	7,372	7,203	7,019	6,804	6,860	6,687	6,541	6,688	6,829	7,195	7,527	7,044
Minimum Months												
7,208	6,951	6,905	6,746	6,520	6,391	6,053	6,307	6,268	6,560	6,547	6,601	6,590

NOTE: 1. Subregion runoff is that which originates in the subregion.
2. Twenty percent and eighty percent represent the runoff available 20 and 80 percent of the time.

Average Discharge for Selected Stations In this section, additional data are given for each of the selected sites listed on table 141. Monthly discharge values are shown on tables 143 to 153. These flows reflect regulation and use under 1970 development.

Figures 258 to 268 are flow hydrographs for seven conditions: maximum, mean, and minimum monthly flows; monthly flows for the maximum and minimum years during the base period; and those monthly flows which are equaled or exceeded 20 percent and 80 percent of the time.

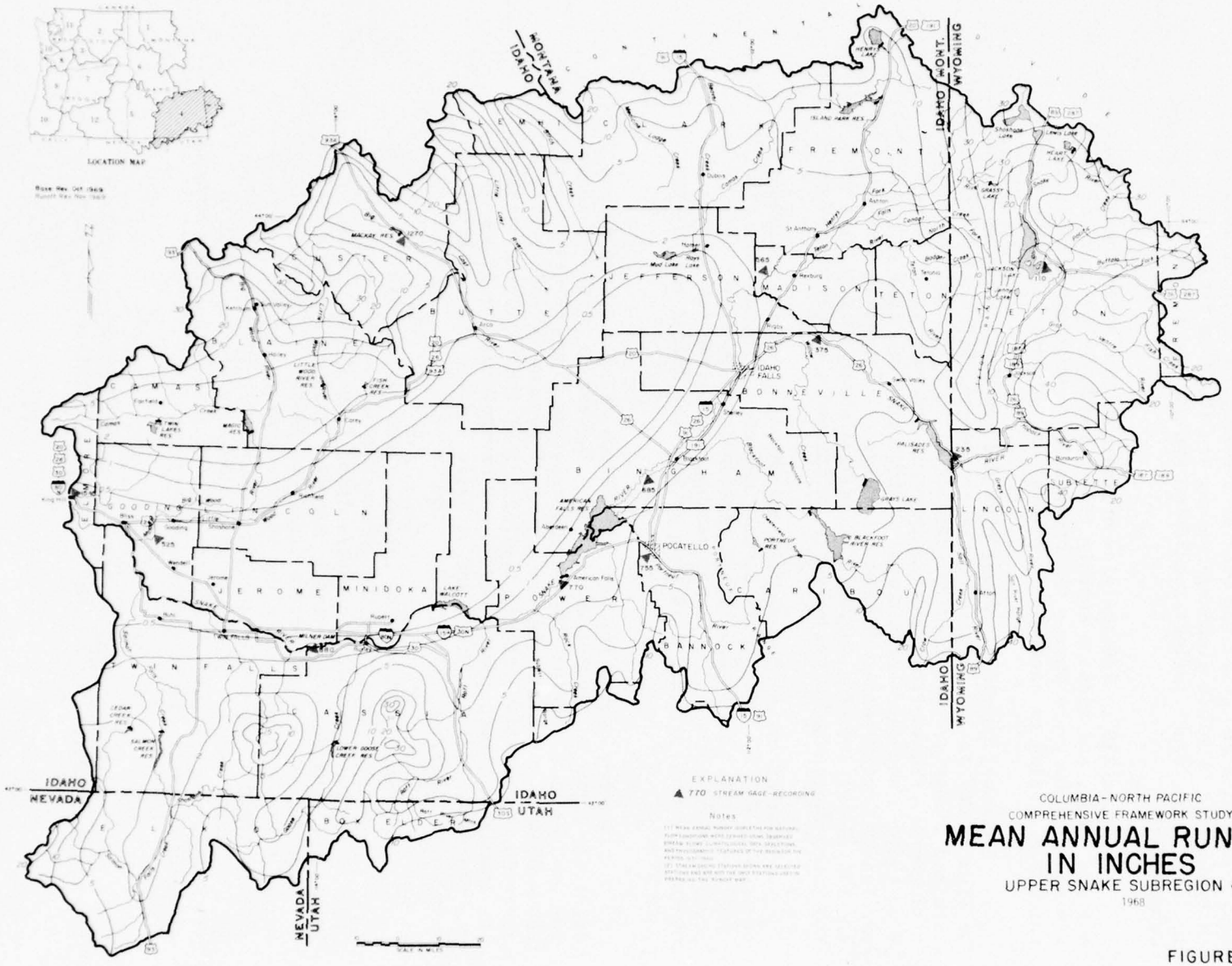
Frequency curves of annual high and low discharges are shown on figures 269 to 279. These curves present the highest average flow and lowest average flow for periods of 1, 3, 6, and 12 consecutive months. Where flows are highly regulated such as at Milner Dam, they do not resemble a normal distribution of highs and lows; and the frequency curves diverge severely. At the other extreme are the closely related curves at King Hill where a large part of the total discharge is ground-water inflow and thus quite uniform.

Duration curves for monthly and annual flows are presented on figures 280 to 290. These curves indicate the percent of time that any given flow is equaled or exceeded at each site. The occurrence of these flows is not necessarily during consecutive months or years, but may have been at any time during the 30-year base period.

Frequency curves for peak discharges at some of the selected sites are shown on figures 291 to 297. The entire period of record was used at each station, but only a selected group of stations is shown because variations in the amount of regulation made peak frequency computations rather meaningless at the remaining sites. For comparison, both the regulated and unregulated curves are shown for the Snake River at Moran and at Heise and for the Blackfoot River near Blackfoot.

Dependable yield at the various sites is shown in tables 154 to 164. The data shown are the lowest mean flows that occurred (within the base period) for intervals of 1 to 10 consecutive years. Each table must be interpreted independently because of the variety of conditions existing. For instance, yield for the Snake River at Moran is high (73 percent of the 30-year average for the lowest year of the period), while at Milner it is only 16 percent. This variance shown on the tables is mainly because of the amount of regulation and use above the different stations rather than because of differences in discharge characteristics.

Variation in Discharge Long-term variations in discharge for the Snake River near Heise, and in precipitation for Ashton,



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES

UPPER SNAKE SUBREGION 4

1968

FIGURE 256

Idaho, are presented in figure 298. Means for the base period (1929-58) and for the entire period of record are shown on both graphs. The unregulated discharge of the river near Heise averages 6,490 cfs during the base period, which is 95 percent of the average for the 56-year period of record. Comparison of records for precipitation also shows that the 30-year mean is nearly the same for the longer record. In this case, the 30-year mean at Ashton is 103 percent of the 65 years of continuous record (one of the longest records in the area). Five-year moving averages are also shown since annual values, particularly for precipitation, vary greatly from one year to another, obscuring the general trends.

Variations in monthly and annual flows at selected sites are shown by the duration curves in figures 280 to 290.

Seasonal variations can be seen in the hydrographs of figures 258 to 268. A normal cycle of low winter runoff, a high spring flow due to snowmelt, and receding flows throughout the summer are characteristic at most sites. However, at Moran (below Jackson Lake) and at Neeley (below American Falls Reservoir), Snake River summer flows decrease less than at other locations; this is due to storage releases. On the Blackfoot River near Blackfoot, the increase in flow during the fall is probably the result of cessation of upstream irrigation diversions.

Streamflow Travel Time Data on time of travel are available only for the Snake River, and for just that part where it is necessary for the scheduling of irrigation releases. Figure 299 shows travel times for three different magnitudes of flow between Moran and Milner. Between the Blackfoot gage and Milner, the river flows through three rather large reservoirs which disguise any variation in travel time due to the magnitude of flow.

River Profiles River profiles for the Upper Snake River and selected tributaries are shown in figure 300.

Narrative continued on page 391

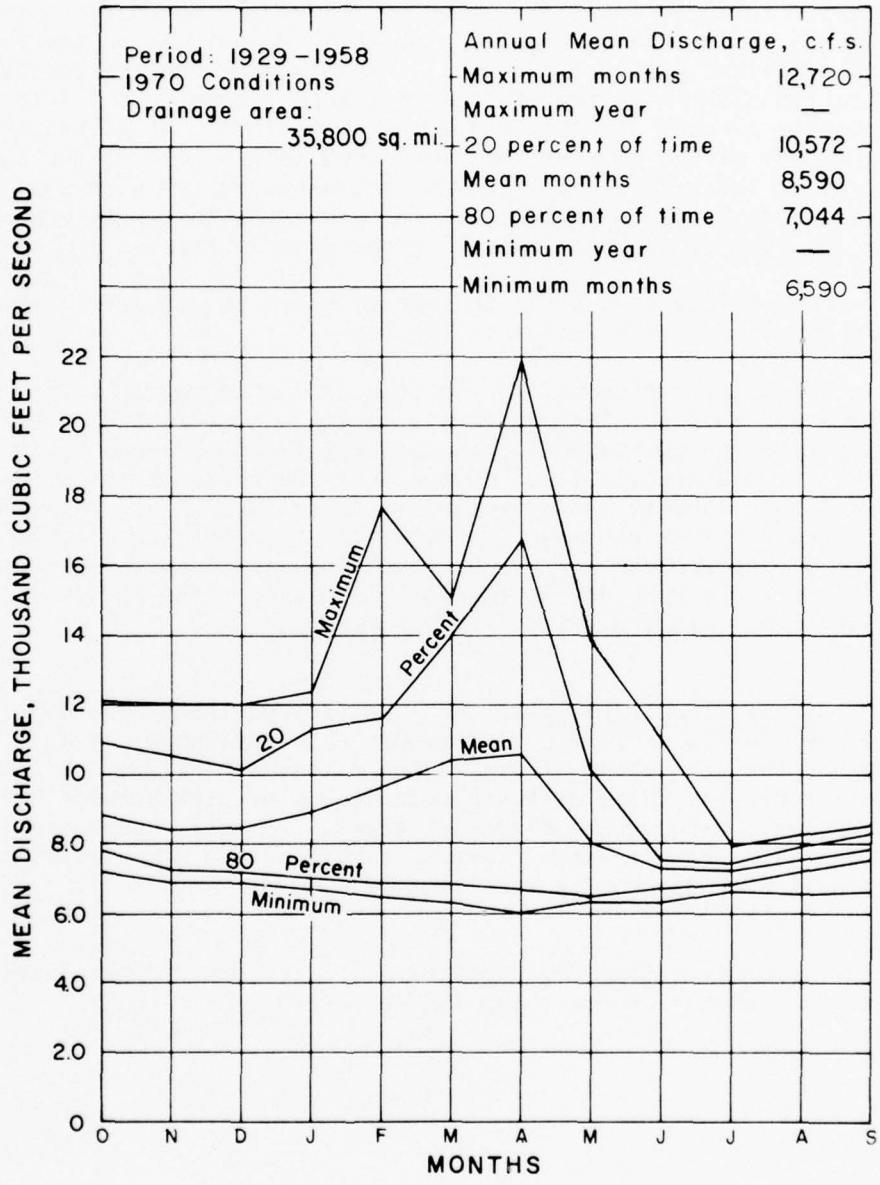


Figure 257 Monthly discharge, Upper Snake Subregion.

Table 143. Modified Mean Discharges in CFS, Snake River at Moran, Wyoming

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										3509	3509	2410	0
1929	511	400	550	480	50	50	50	270	3749	2940	3049	2711	1239
1930	371	240	450	390	50	50	50	60	2529	2870	3319	2711	1096
1931	699	410	330	330	50	50	50	50	4959	3699	3400	3790	1488
1932	350	329	410	429	50	60	50	50	529	2200	5068	4990	1213
1933	50	50	50	50	50	50	61	50	50	3010	4998	5010	1131
1934	340	329	320	460	380	60	61	3389	3501	3489	550	240	1100
1935	450	460	429	489	411	420	760	2730	3501	3499	1889	329	1288
1936	359	390	320	650	661	450	50	60	61	1489	3259	5000	1061
1937	289	220	350	400	59	50	50	50	2149	3000	4998	4990	1390
1938	400	380	520	480	50	50	50	50	50	3429	3480	2881	995
1939	511	471	499	460	59	50	50	839	3220	2849	3109	2630	1235
1940	371	240	311	429	50	50	50	250	3450	3499	4998	5000	1560
1941	420	410	60	60	59	60	50	50	3129	3489	3489	4321	1303
1942	660	529	660	450	50	60	50	60	50	2169	2989	4570	1030
1943	89	50	50	60	59	60	61	1060	4810	4579	2350	2610	1324
1944	550	501	380	320	50	60	50	241	3660	3299	3359	2560	1254
1945	311	430	320	390	59	50	50	60	3220	3499	3489	1840	1150
1946	470	529	569	540	50	60	50	3369	3739	3219	3099	2800	1551
1947	559	491	540	499	50	50	50	2860	3760	2889	2800	2949	1466
1948	470	501	441	480	61	50	61	1850	5170	3200	3130	2681	1509
1949	410	501	540	480	59	60	61	4029	3529	2660	3179	2739	1531
1950	520	450	390	580	59	60	109	2169	4131	3239	2190	3760	1476
1951	629	671	569	650	730	829	770	3370	3081	2569	2480	3820	1685
1952	629	450	650	620	760	60	1050	3610	4220	3499	3499	2780	1822
1953	340	271	499	670	50	60	50	60	4349	3000	3000	2850	1270
1954	350	410	441	641	59	60	180	4258	3870	3489	3499	3020	1701
1955	420	440	400	429	59	60	50	50	3521	3499	3229	2670	1241
1956	499	580	829	740	61	50	1800	4379	5860	3010	3499	3030	2030
1957	520	891	650	580	59	50	220	1410	5420	3010	3109	2270	1521
1958	420	370	530	450	59	60	50	2299	2580	2150	2800	2590	1204
Mean	432	413	435	456	145	107	203	1435	3195	3082	3244	3138	1362

Table 144. Modified Mean Discharges in CFS, Snake River at Idaho-Wyoming Stateline

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										10192	6434	4936	0
1929	2689	2339	2018	1928	1605	1463	2346	7380	12327	7997	5389	5175	4399
1930	2380	1998	2003	1681	1355	1610	5085	6776	10863	7284	6062	4934	4346
1931	3141	2270	1917	1660	1468	1476	2712	3993	9495	5590	4774	5238	3650
1932	1805	1755	1608	1541	1115	1228	3015	9595	11021	7922	7657	7205	4630
1933	2021	1894	1584	1520	1344	1416	2712	5686	10744	6545	6928	6786	4106
1934	1971	1901	1655	1685	1566	1488	2765	7974	6289	5268	1720	1346	2980
1935	1644	1620	1488	1467	1413	1465	4070	9289	13532	8299	3932	2072	4202
1936	1917	1850	1580	1683	1664	1537	4680	15265	12078	6244	5769	7302	5136
1937	2213	1956	1826	1672	1259	1353	1941	8725	9769	6548	6686	6719	4237
1938	2072	1864	1977	1732	1272	1322	3679	8758	13016	9463	5998	5008	4695
1939	2652	2286	2081	1928	1413	1719	5590	8863	9489	6849	5146	4583	4396
1940	2094	1775	1663	1650	1259	1449	2988	6431	8497	5574	6296	6601	3859
1941	1906	1817	1294	1203	1184	1429	2712	6876	9879	6774	5689	6363	3936
1942	2496	2171	2141	1691	1274	1319	5296	6865	8815	6712	4888	6413	4181
1943	1824	1602	1460	1302	1333	1304	9126	12286	17666	14197	5907	5128	6109
1944	2839	2578	2150	1876	1544	1403	2655	5044	12025	7758	5914	4388	4098
1945	2002	2144	1857	1732	1371	1294	1714	6462	12452	10815	6724	4475	4437
1946	2733	2548	2246	1987	1474	1745	6726	12772	13552	7979	5694	4975	5384
1947	2800	2504	2356	1881	1560	1746	3104	13824	13404	8945	6089	5005	5291
1948	2624	2459	2078	1935	1438	1436	2676	11002	16233	7148	5315	4512	4907
1949	2138	2081	1933	1618	1335	1364	4040	14380	13362	6790	5351	4612	4935
1950	2650	2370	2000	2041	1402	1540	3717	10880	19771	13041	5619	6408	5968
1951	3224	2961	2476	2215	2254	2067	5591	16120	16581	11519	7158	6395	6568
1952	3088	2408	2236	2122	2064	1309	5158	16182	15547	7589	6037	4850	5722
1953	2485	2037	1977	2187	1436	1556	2597	4862	17053	8920	5467	4791	4618
1954	2117	2034	1790	1950	1351	1470	3269	16042	13514	11122	6255	5049	5526
1955	2219	2109	1815	1797	1382	1328	1755	5858	13260	7914	5496	4415	4121
1956	2172	2106	2714	2426	1470	1467	7139	18919	24528	10148	6564	5228	7075
1957	2561	2375	2389	2234	1515	1452	2410	10662	19949	11125	5863	4358	5590
1958	2307	2010	2044	1816	1357	1276	2018	13288	11304	5167	4514	4186	4292
Mean	2360	2128	1946	1806	1449	1468	3776	10037	13200	8243	5665	5151	4780

Table 145. Modified Mean Discharges in CFS, Snake River near Heise, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										12977	8379	6980	0
1929	4839	4159	3699	3569	3373	2419	1919	11948	1190	10967	7608	9751	6365
1930	2919	2830	2839	2039	2061	1320	4091	9338	14240	11218	10847	10220	6179
1931	2330	2129	2060	1769	1791	1309	1949	8018	11640	12107	13148	9561	5676
1932	2989	1800	1779	1769	1800	2019	2501	6658	10371	13197	13297	9361	5646
1933	2670	1871	1819	1839	1802	1790	1960	7159	10410	13288	12488	9880	5608
1934	2880	1830	1779	1790	1771	1819	2810	6449	9430	9437	10458	6480	4765
1935	2559	1770	1750	1750	1732	1750	2170	7159	10260	16237	12637	7810	5666
1936	2950	1820	1759	1800	1800	1769	2030	12148	13310	12107	12008	10121	6152
1937	2819	2070	2070	1790	1802	1769	1681	8668	10781	12387	13037	9440	5722
1938	2860	1820	1829	1779	1782	1819	1850	14536	11361	11818	8358	8400	5715
1939	3829	3470	3499	3600	3022	2800	2911	12517	12300	10938	8198	8561	6326
1940	2870	2050	2029	2019	1810	1509	1240	8328	11100	13158	10688	8361	5431
1941	2819	1800	1759	1769	1760	1280	1210	6868	12981	13158	11987	7990	5473
1942	2919	1871	1870	1790	1791	1280	1400	8858	11700	11167	12338	9111	5533
1943	2849	2111	2089	2340	2272	2229	17100	14767	13991	15187	8348	7390	7573
1944	5049	4680	3870	2819	2071	1800	1701	8158	14420	11107	10738	8470	6252
1945	2839	2101	1979	2550	2261	2210	1681	9488	14260	13748	8719	6331	5705
1946	4858	4600	3989	3569	3061	3480	9370	16686	14371	11047	7858	6200	7448
1947	4769	4159	4019	3299	3112	3379	6311	16987	12480	11258	8239	6731	7091
1948	4579	4331	3870	3699	3101	2950	1600	16067	18080	11107	7808	6169	6962
1949	3728	3650	3019	3089	2292	2429	11500	15787	11450	10907	7818	6430	6864
1950	3950	2970	2849	2899	2571	4198	12610	14107	14920	15606	6849	8280	7756
1951	5499	5149	4519	4150	4432	4058	15361	16286	13830	13628	9538	8190	8735
1952	5480	4670	4328	4140	4071	3309	12761	17026	15151	10948	7779	6351	8004
1953	4258	3770	3659	3499	2751	2709	2949	8678	17621	10998	7868	6060	6249
1954	4270	3840	3519	3619	3013	3010	10630	15676	11420	11517	7878	7290	7162
1955	4080	3721	3210	3070	2742	2190	1840	7488	13391	10917	10798	8670	6027
1956	2819	2119	2099	3480	3802	6849	15460	18636	21571	11028	7989	6169	8497
1957	4819	4180	4179	3819	3413	3299	6131	12697	19981	13657	7789	6141	7525
1958	4598	4111	4049	3639	3312	3099	2570	16206	12690	10658	7439	6080	6567
Mean	3691	3048	2860	2759	2545	2522	5310	11782	13380	12153	9720	7866	6489

Table 146. Modified Mean Discharges in CFS, Henrys Fork near Rexburg, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										889	559	871	0
1929	1619	1729	1689	1600	1580	1460	1671	2400	2600	839	569	729	1539
1930	1380	1471	1320	1029	1250	1419	1901	660	691	580	660	650	1082
1931	1169	1180	930	899	1011	1111	220	850	560	530	629	820	826
1932	480	550	889	829	830	829	509	2829	2721	1930	1340	1271	1253
1933	880	1139	959	1060	1180	1410	1610	1979	3091	769	450	770	1271
1934	600	1000	829	899	991	920	1050	1039	840	1340	1419	1871	1066
1935	441	190	680	680	681	711	139	1229	1570	969	870	1410	798
1936	680	990	930	920	930	920	1311	2670	1511	750	680	460	1063
1937	820	1040	839	839	870	990	860	2169	1719	1270	1140	939	1127
1938	899	850	930	911	910	1159	1450	3709	3020	850	610	820	1345
1939	1400	1750	1590	1590	1611	1790	3220	2860	1091	800	620	650	1580
1940	1309	1200	1000	1080	1110	1340	2210	2689	1150	680	600	660	1253
1941	1239	339	1070	1080	1031	1060	1390	2169	1220	1619	1480	1729	1289
1942	1260	1129	1070	940	870	1130	1580	2190	2560	680	600	739	1229
1943	1060	1311	1140	1489	1512	2239	3830	3280	3329	1509	699	1271	1886
1944	1959	2380	1950	1829	1850	1769	1630	1320	1550	860	699	970	1562
1945	1340	1471	1200	1239	1602	1689	1660	2629	2929	889	769	1350	1561
1946	1860	2081	1979	1880	1881	2169	3580	3130	1240	730	699	1040	1854
1947	1880	1640	1270	1330	1681	1639	1760	3029	1719	969	750	1091	1562
1948	1660	1640	1390	1600	1821	1800	2360	2790	3081	850	800	1091	1737
1949	1590	1580	1260	1200	1541	2000	2539	4309	2721	880	759	909	1774
1950	1769	1650	1280	1429	1831	2080	2570	2460	3380	1520	1020	1400	1862
1951	2060	2301	2109	1880	2022	2000	2881	3070	1660	780	980	1160	1907
1952	2179	2070	2019	2000	1880	2470	3460	6219	3410	920	889	1109	2387
1953	1350	1830	1959	2169	1921	1730	1580	1720	3081	880	800	909	1657
1954	1369	1610	1419	1660	1872	1660	1929	3049	1471	870	800	1101	1566
1955	1559	1511	1460	1829	1741	1769	1790	1359	2101	899	750	850	1465
1956	1520	1650	1600	1650	1911	2210	3190	3709	3129	1000	860	1360	1979
1957	1909	2129	1610	1520	2011	2480	2101	4750	3440	1120	1010	1460	2128
1958	1920	1760	2080	1839	1982	1750	1960	3459	1329	860	810	1150	1742
Mean	1372	1439	1349	1364	1463	1590	1931	2658	2130	972	826	1058	1512

Table 147. Observed and Estimated Mean Discharges in CFS, Blackfoot River near Blackfoot, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										86	135	109	0
1929	169	240	130	99	142	122	373	259	150	46	34	138	158
1930	182	240	210	115	175	133	296	52	113	33	211	91	154
1931	159	240	148	99	108	76	138	102	5	33	167	15	108
1932	60	118	63	18	21	31	136	244	259	68	31	45	91
1933	154	271	109	62	56	46	129	332	25	20	3	24	103
1934	60	166	273	273	272	182	57	2	0	0	0	0	106
1935	0	27	99	60	22	47	97	98	32	8	0	0	41
1936	94	170	140	102	57	72	217	133	215	34	62	35	111
1937	119	222	259	63	45	68	96	202	118	26	5	2	102
1938	125	215	291	130	119	115	365	314	141	150	15	10	166
1939	272	287	190	180	169	263	385	46	47	8	2	35	157
1940	177	185	148	101	101	132	134	29	47	2	0	66	93
1941	176	200	166	150	150	189	173	63	59	5	39	50	118
1942	207	230	203	98	85	99	336	250	44	13	7	37	134
1943	133	284	262	242	166	223	497	98	217	21	20	64	185
1944	242	289	218	120	83	122	262	93	166	11	8	40	138
1945	122	297	229	171	202	207	158	221	176	37	101	192	176
1946	408	405	215	202	126	223	538	390	255	70	60	114	251
1947	211	316	291	148	139	211	249	52	114	28	68	72	158
1948	179	319	275	135	94	180	271	413	183	60	50	54	185
1949	176	321	200	93	29	93	264	207	109	24	46	40	134
1950	158	229	171	86	133	198	460	577	407	78	107	239	237
1951	468	339	332	184	299	273	550	600	124	54	197	103	294
1952	361	516	306	241	250	270	548	502	190	80	75	86	285
1953	150	296	172	193	200	128	183	262	281	39	46	20	164
1954	190	318	167	122	151	122	175	70	67	26	33	40	123
1955	231	346	190	117	83	78	134	73	74	37	28	34	119
1956	104	333	233	174	99	195	385	106	74	23	41	76	153
1957	184	319	158	75	168	184	380	901	153	26	47	72	223
1958	158	269	158	76	144	122	424	304	66	26	20	50	151
Mean	181	267	200	131	129	147	280	233	130	36	51	61	154

Table 148. Observed Mean Discharges in CFS, Portneuf River at Pocatello, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										96	94	108	0
1929	174	235	215	200	213	429	466	485	155	80	86	134	239
1930	268	269	278	234	317	317	208	109	72	54	80	86	190
1931	208	255	229	224	247	332	255	86	59	33	42	61	169
1932	85	158	210	210	203	324	466	436	203	80	78	97	212
1933	140	254	220	241	247	315	390	371	141	60	73	84	211
1934	94	195	220	228	231	179	62	41	47	29	36	59	118
1935	78	91	195	190	218	278	350	221	82	42	37	55	153
1936	76	170	179	207	216	314	551	485	131	68	111	108	218
1937	125	237	229	205	213	328	430	382	94	80	70	87	207
1938	112	188	276	246	323	382	509	389	116	141	81	103	238
1939	179	286	288	273	250	449	457	145	61	49	59	96	215
1940	106	158	210	255	275	325	281	101	57	50	44	92	162
1941	102	150	207	197	290	369	385	268	111	72	99	106	196
1942	130	198	262	259	267	324	593	416	175	68	54	92	236
1943	128	237	268	289	306	420	783	468	329	104	111	126	297
1944	182	292	294	302	294	366	418	325	351	57	50	76	250
1945	124	244	254	281	396	358	417	610	541	132	141	218	308
1946	270	303	353	338	303	511	783	644	193	104	124	155	340
1947	283	351	369	311	389	406	385	221	84	41	75	101	250
1948	211	262	254	270	390	363	550	616	153	67	75	106	276
1949	239	281	267	236	229	408	592	390	156	70	67	87	252
1950	218	276	285	320	425	554	699	764	497	190	146	230	383
1951	304	353	328	291	414	410	521	353	97	59	127	123	281
1952	226	319	304	288	270	324	699	797	234	106	122	134	318
1953	150	292	325	389	350	376	415	281	341	63	80	82	261
1954	153	264	291	278	314	367	381	119	64	46	46	61	198
1955	98	171	233	224	231	268	309	167	94	39	60	69	163
1956	99	232	268	309	261	380	533	291	72	28	49	62	215
1957	102	230	252	228	413	395	339	654	301	50	63	87	258
1958	145	262	291	280	425	433	555	463	86	41	68	86	260
Mean	160	240	262	260	297	367	459	370	170	70	78	102	236

Table 149. Modified Mean Discharges in CFS, Snake River at Neeley, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										12628	11798	6690	0
1929	3569	2580	3099	2200	2932	3470	4670	10437	11161	13037	11697	6341	6295
1930	2089	10	10	10	2532	2109	6551	10538	11450	12837	11888	6911	5596
1931	1779	291	70	50	11	689	4790	10967	11640	13117	11707	6790	5193
1932	2519	230	29	111	40	380	4559	10948	11321	13028	11998	6840	5189
1933	2010	30	0	41	31	410	4701	10418	11351	12936	12088	6741	5098
1934	2120	91	50	99	0	641	4660	9519	9781	11567	10177	5450	4545
1935	2759	319	120	150	0	610	4610	10158	10840	12197	10858	5891	4911
1936	2200	271	200	0	0	270	5000	11258	11050	12847	11787	6640	5149
1937	2029	30	0	229	0	559	4359	10548	11151	12948	11878	6531	5058
1938	2219	50	0	120	11	480	4680	10437	10951	12338	11707	6800	5017
1939	1909	10	0	2359	4432	4839	6759	10049	11151	12837	11787	6630	6077
1940	1930	40	111	60	0	820	4270	10647	11450	12637	11637	6290	5013
1941	1880	40	10	60	0	499	4680	10738	11161	12727	11587	6440	5020
1942	2019	0	20	410	20	530	5170	10247	10850	12927	11787	6559	5080
1943	2460	10	10	2429	2461	4658	16920	11398	11050	12637	11688	6580	6876
1944	4779	3050	3119	4410	3322	4649	4420	10528	10541	12927	11808	6580	6703
1945	2070	71	0	220	1402	3200	4121	10037	11161	12538	11808	6290	5273
1946	3680	119	2480	4410	4362	7678	13141	14267	11240	12628	11608	6380	7693
1947	2200	301	2670	2569	4333	6668	8690	13367	11060	12637	11587	6590	6914
1948	2270	220	2719	2530	3882	5699	4990	12808	11250	12828	11497	6450	6451
1949	3728	360	1200	4289	2121	7268	14520	13628	11151	12828	11777	6810	7510
1950	1920	61	0	1480	3602	7618	16221	11488	10840	12527	11598	6580	7007
1951	5439	4430	4439	4899	9405	8418	18940	13387	10860	12628	11398	6790	9241
1952	5408	3521	3470	4509	4842	8589	16920	16987	11060	12538	11798	6580	8867
1953	4140	2600	810	4328	4404	5239	5491	9649	10850	12727	11587	6711	6564
1954	2179	109	750	2779	4494	6579	13490	12278	10840	12738	11707	6600	7059
1955	2029	139	200	870	4443	5109	4701	10247	11050	12637	11598	6541	5811
1956	2359	81	0	89	4402	8658	18680	14958	13131	12548	11507	6690	7757
1957	4468	2640	2559	4398	4213	7299	8779	12138	14381	12828	11697	6701	7699
1958	5319	3420	3480	3449	4874	7389	5660	13857	11060	12538	11697	6450	7463
Mean	2850	837	1054	1786	2549	4035	8171	11600	11227	12693	11634	6539	6271

Table 150. Modified Mean Discharges in CFS, Snake River at Milner, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										320	330	101	0
1929	1969	2901	3499	3109	3103	3680	881	0	10	330	330	91	1654
1930	260	160	359	460	3241	1899	2070	0	0	330	320	91	748
1931	171	309	320	289	220	190	250	330	91	340	330	91	245
1932	320	339	371	400	310	270	281	311	71	320	330	81	284
1933	311	271	429	289	270	270	301	280	101	330	320	91	273
1934	260	271	390	410	350	200	281	359	129	330	330	91	284
1935	320	319	441	460	391	289	329	390	129	340	320	101	320
1936	311	339	489	429	690	460	319	420	0	340	320	91	351
1937	250	339	499	470	380	330	0	10	0	340	330	81	253
1938	299	319	470	470	321	289	0	0	0	330	340	81	244
1939	200	301	470	2639	4764	4880	2580	10	0	330	320	101	
1940	241	260	400	420	461	641	10	10	0	330	340	81	265
1941	260	281	450	429	470	270	339	0	10	320	320	81	269
1942	280	650	590	429	310	400	491	10	0	320	320	91	325
1943	390	329	680	2899	2841	4598	12640	1260	0	330	320	81	2180
1944	3099	3129	3410	4750	3581	4150	139	10	10	320	340	91	1919
1945	270	250	429	499	1771	2979	0	0	10	330	340	91	576
1946	1779	271	2940	4680	4703	7548	8761	4128	10	320	340	81	2955
1947	380	380	2979	2959	4854	6538	4311	3029	10	330	320	91	2171
1948	311	309	3089	3140	4452	5468	810	2070	0	320	330	101	1700
1949	1810	339	1499	4728	2681	7499	10240	3689	0	320	311	101	2770
1950	210	329	550	2060	4103	7519	12040	1350	10	320	330	81	2385
1951	3819	4691	4969	4950	10267	8328	14660	3150	10	320	330	91	4583
1952	3689	3529	3819	4680	5023	8198	12640	6649	10	330	330	81	4077
1953	2499	2630	1120	4750	4714	5099	1610	10	0	320	320	101	1917
1954	241	240	1190	3200	4784	6278	9311	1839	10	330	340	101	2299
1955	350	360	489	1180	4804	4909	420	10	0	330	330	101	1086
1956	280	250	420	429	4863	8558	14500	4719	2481	340	340	91	3083
1957	2810	2670	3000	4810	4854	7288	4701	1899	3329	320	330	101	2998
1958	3719	3501	3779	3759	5454	7499	1481	3319	10	330	330	91	2767
Mean	1037	1009	1452	2140	2964	3885	3879	1308	212	328	329	90	1545

Table 151. Observed Mean Discharges in CFS, Big Lost River Below Mackay Reservoir Near Mackay, Idaho

Water Table	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										463	190	170	0
1929	192	54	73	99	112	122	116	190	644	325	153	156	186
1930	163	49	68	91	99	111	104	320	939	382	200	170	225
1931	185	67	85	106	115	120	113	197	422	224	177	146	163
1932	150	59	68	81	92	102	103	400	889	652	302	171	256
1933	182	62	80	94	108	120	116	115	1050	272	156	141	207
1934	148	119	60	78	92	98	103	275	203	127	112	123	128
1935	133	57	60	78	90	101	104	145	817	644	351	165	229
1936	179	76	96	91	101	111	109	338	454	433	172	160	194
1937	208	66	68	89	99	107	106	215	424	307	146	139	165
1938	141	91	60	75	83	94	104	327	1711	990	423	150	355
1939	151	244	146	151	171	182	161	327	447	428	309	175	241
1940	213	69	72	91	111	117	114	413	711	457	247	99	227
1941	107	66	85	107	121	128	123	325	718	515	346	190	236
1942	146	114	128	193	196	172	271	428	961	764	444	148	331
1943	122	89	128	161	173	176	197	756	1336	1070	533	254	418
1944	140	134	207	179	148	180	171	402	1227	1029	593	255	390
1945	99	119	208	176	177	159	161	273	686	685	564	240	297
1946	78	97	104	120	130	146	215	600	827	675	441	123	298
1947	68	91	114	169	182	190	190	686	723	688	354	257	310
1948	101	62	86	102	108	119	146	395	1192	676	467	202	305
1949	63	79	94	115	132	148	150	475	718	580	364	205	261
1950	91	67	81	98	110	114	114	358	568	751	449	141	247
1951	60	82	94	109	119	125	200	683	928	722	514	262	326
1952	124	116	180	200	209	207	239	1023	1249	750	572	129	417
1953	104	114	127	192	168	151	148	346	872	933	532	232	328
1954	107	76	91	104	114	125	150	585	534	751	423	277	280
1955	211	45	70	91	105	111	106	179	718	514	439	215	234
1956	171	54	63	83	92	104	113	789	1571	828	486	208	381
1957	122	76	88	102	114	120	124	400	1319	829	550	119	331
1958	120	118	125	135	144	150	165	1192	1265	715	483	313	412
Mean	136	87	100	119	127	134	144	439	871	624	377	186	279

Table 152. Observed and Estimated Mean Discharges in CFS, Big Wood River near Gooding, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										15	8	3	0
1929	29	92	42	52	54	46	18	18	17	15	0	2	32
1930	23	77	78	65	54	39	15	29	29	23	7	0	36
1931	47	39	39	26	27	18	3	10	5	8	18	10	21
1932	11	54	28	21	26	42	76	59	55	34	28	17	37
1933	37	81	42	41	76	98	126	174	30	26	20	20	64
1934	23	67	47	31	50	16	13	18	20	18	18	15	28
1935	11	84	24	16	27	16	12	36	40	23	24	3	26
1936	5	67	44	33	45	130	218	60	96	41	33	32	67
1937	26	69	37	29	38	78	136	91	89	26	29	27	56
1938	13	55	132	46	41	267	1207	1933	1244	494	46	54	462
1939	57	108	36	24	47	753	671	83	39	28	31	24	159
1940	26	47	28	37	137	96	180	75	40	44	28	79	67
1941	20	59	33	23	70	49	71	47	77	42	46	57	49
1942	49	101	54	59	169	276	825	678	425	36	37	72	231
1943	31	101	117	351	505	1374	2948	1068	1193	420	78	77	686
1944	91	153	111	135	150	215	351	390	271	62	70	91	174
1945	62	118	72	83	310	202	373	234	218	59	70	103	157
1946	78	173	145	80	205	914	889	506	296	44	63	109	292
1947	125	148	124	89	204	283	452	192	202	37	60	91	166
1948	39	92	140	99	143	228	104	83	77	42	47	156	105
1949	57	148	54	36	29	550	202	102	131	41	49	109	126
1950	41	79	54	60	177	236	713	486	242	70	98	155	200
1951	101	148	172	115	407	493	1484	1281	365	80	86	134	404
1952	54	195	93	67	530	1083	2129	2668	1035	197	81	138	688
1953	41	69	190	289	177	202	997	299	366	52	57	101	236
1954	39	92	106	176	160	163	328	146	202	49	52	131	136
1955	57	86	127	80	76	154	205	182	103	68	50	97	107
1956	26	118	244	215	101	589	978	1010	913	75	101	146	376
1957	52	244	198	106	468	406	676	1115	716	67	98	168	358
1958	34	59	184	164	211	130	871	1772	845	72	78	173	383
Mean	43	101	93	88	157	305	576	495	313	76	50	80	198

Table 153. Modified Mean Discharges in CFS, Snake River at King Hill, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										7335	7463	7660	0
1929	9484	10769	10054	9930	9800	10816	7502	6540	7440	7276	7563	7998	8760
1930	8034	7260	7193	6787	9892	8154	8674	7382	6892	7202	8114	8163	7796
1931	7813	7373	7039	6966	6706	6774	6738	6930	6588	6561	6920	7136	6965
1932	7315	6183	6906	6746	6702	7015	6687	6946	6595	6800	7086	7591	6966
1933	7808	7531	7106	6998	6667	6829	6869	6802	6467	6584	6915	7420	7002
1934	8071	7741	7806	7619	7218	6611	6450	6546	6581	6619	6548	6601	7036
1935	7208	6951	7084	7018	6521	6415	6872	6774	6833	6907	7097	7186	6909
1936	7328	7218	6925	7198	7523	6858	7106	6473	7351	6761	7306	7616	7135
1937	7691	7395	7218	6790	6611	6819	6608	6314	6689	6803	7193	7527	6974
1938	7745	7321	7345	7076	6677	6951	6279	6538	6899	7522	7384	7527	7110
1939	7966	7482	7450	9215	11175	11294	8900	6311	6696	7086	7193	7433	8165
1940	7774	7336	7241	7029	6960	6888	6054	6307	6269	6824	7205	7805	6976
1941	7963	7580	7202	6886	6854	6392	6551	6345	7201	7076	7247	7796	7091
1942	8008	8111	7753	7385	6804	7019	6862	6641	7274	7202	7463	7781	7362
1943	7792	7911	7932	10136	9681	11735	19414	8019	6287	7540	7686	8084	9337
1944	11086	10726	10465	11449	10062	10301	6768	6563	7314	7185	7636	6922	8960
1945	8174	7754	7405	7215	8395	9497	6497	6743	7001	7429	7686	8126	7658
1946	9553	7843	10203	11632	11330	14457	15665	10894	7395	7460	7740	8148	10189
1947	8462	7805	10119	9655	11602	13270	10924	9631	7398	7322	7863	8269	9350
1948	8406	8116	10463	9974	11113	12171	7173	8828	7017	7460	7571	8080	8867
1949	9688	7811	8543	11745	9297	14167	16835	10361	7280	7306	7850	8529	9955
1950	8335	7825	7382	8639	10668	14101	18873	8348	6902	7493	7610	8087	9503
1951	11556	12025	12109	11736	17694	15432	22039	10371	7711	7471	8184	8277	11999
1952	12075	11188	11049	11387	11920	15348	20542	13766	7474	7974	7990	8351	11584
1953	11000	10556	8525	12374	11479	11923	8707	7642	8329	7524	7932	8378	9521
1954	8593	8186	8697	10250	11661	12875	15855	8101	7793	7356	7681	8196	9583
1955	8379	8001	7463	8060	11350	11078	6941	7062	7077	7618	7710	8000	8211
1956	8182	7958	7839	7619	11530	15143	20972	11304	10361	7424	7977	8270	10360
1957	10883	10351	10203	11379	11703	13621	11463	8910	10971	7423	7945	8452	10264
1958	11998	11250	10975	10707	12404	14101	8141	10171	7507	7550	8010	8381	10095
Mean	8814	8418	8458	8922	9593	10471	10498	7987	7320	7227	7545	7904	8590

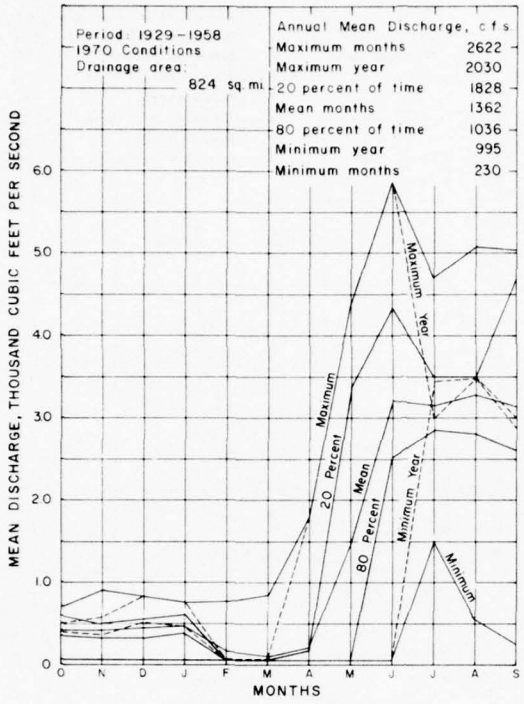


Figure 258 Monthly discharge, Snake River at Moran, Wyo.

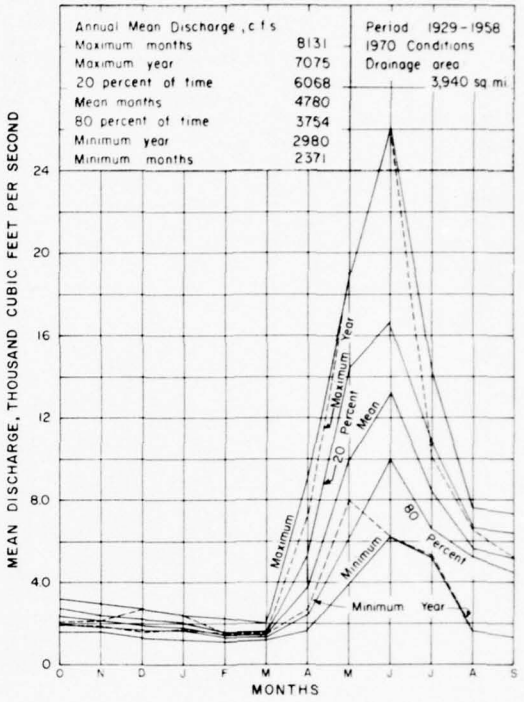


Figure 259 Monthly discharge, Snake River at Idaho - Wyoming State Line

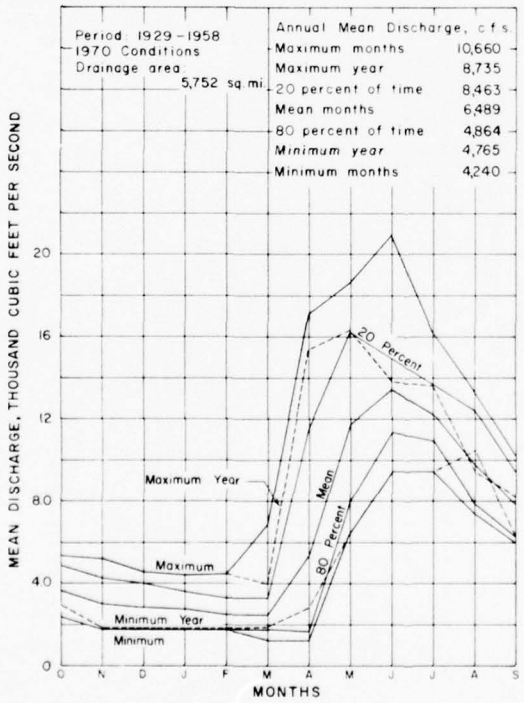


Figure 260 Monthly discharge, Snake River nr. Heise, Ida.

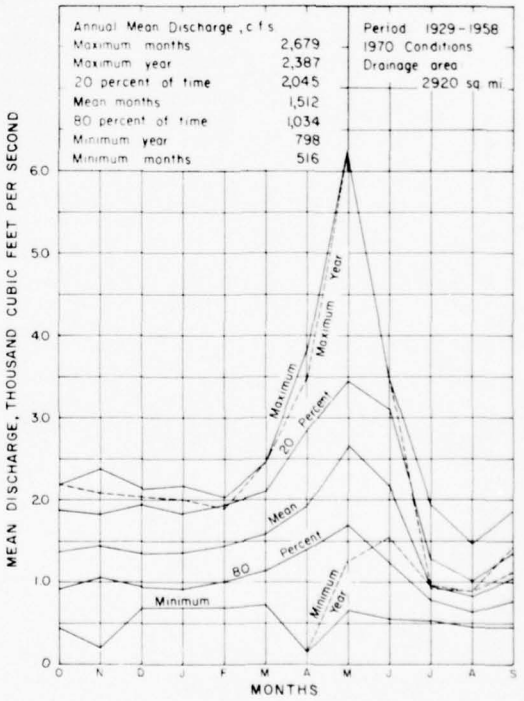


Figure 261 Monthly discharge, Henrys Fork nr. Rexburg, Idaho

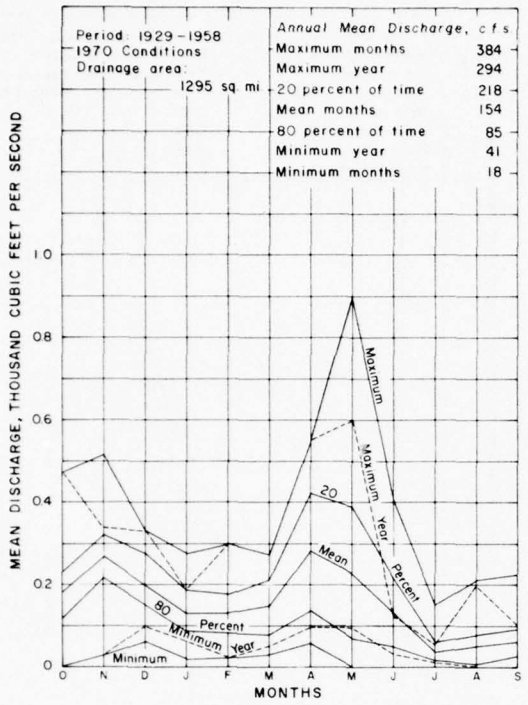


Figure 262 Monthly discharge, Blackfoot River nr. Blackfoot, Ida.

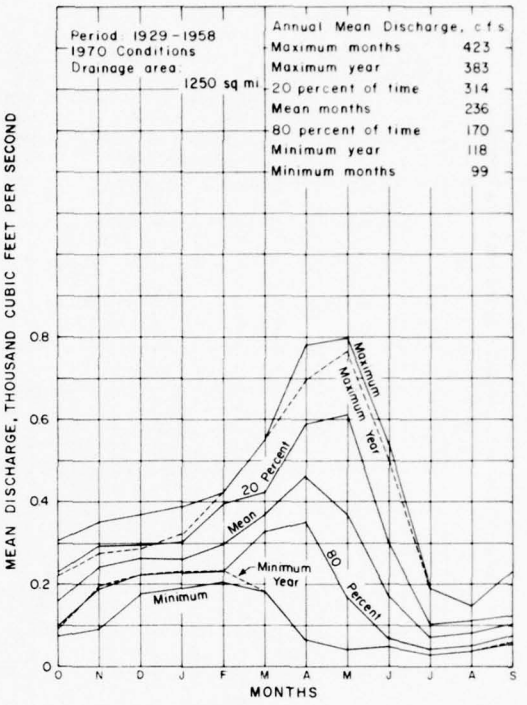


Figure 263 Monthly discharge, Portneuf River at Pocatello, Idaho.

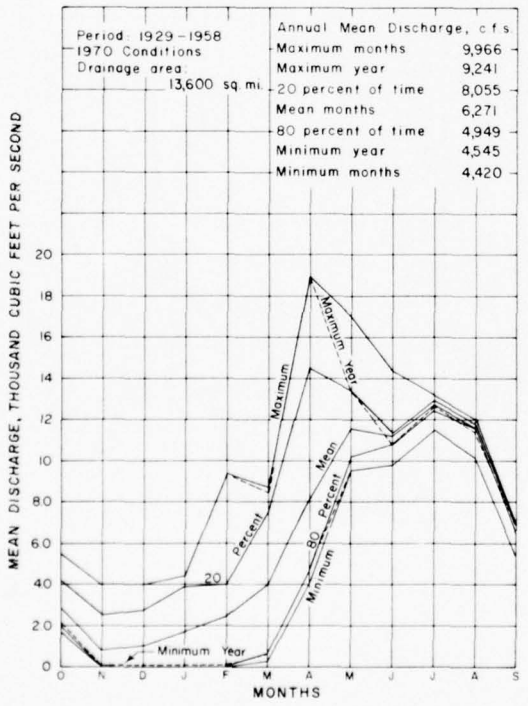


Figure 264 Monthly discharge, Snake River at Neeley, Ida.

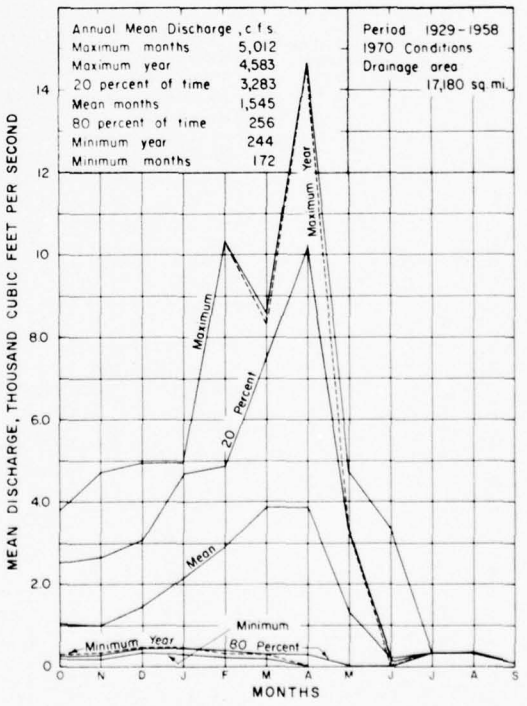


Figure 265 Monthly discharge, Snake River at Milner, Idaho.

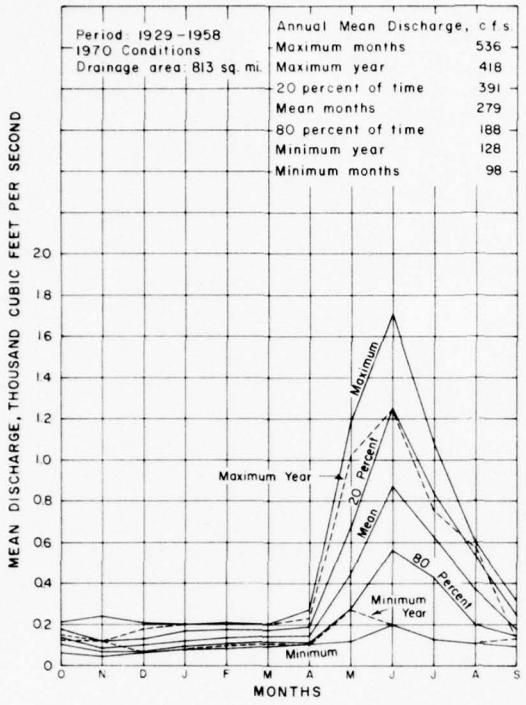


Figure 266 Monthly discharge, Big Lost River below Mackay Reservoir nr. Mackay, Ida.

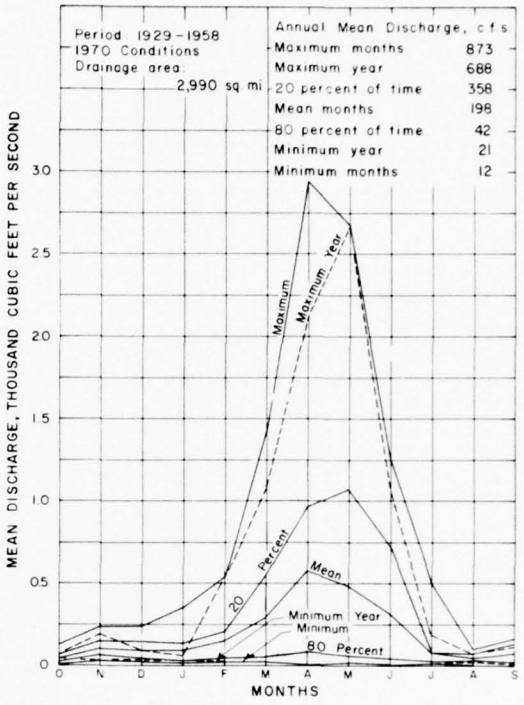


Figure 267 Monthly discharge, Big Wood River nr. Gooding, Ida.

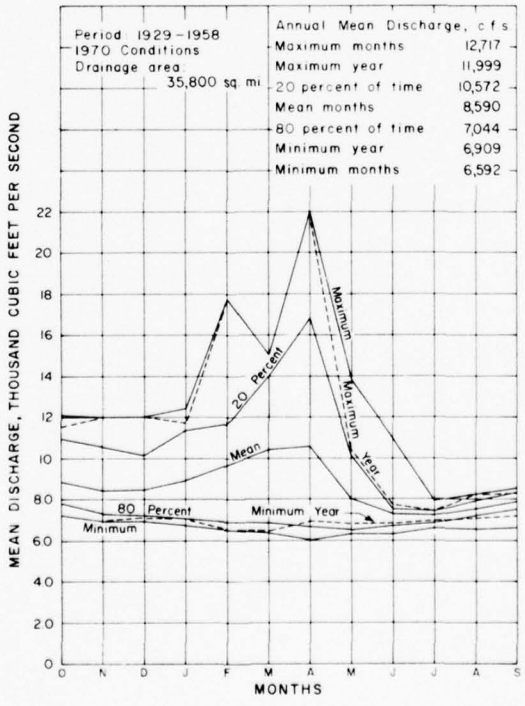


Figure 268 Monthly discharge, Snake River at King Hill, Ida

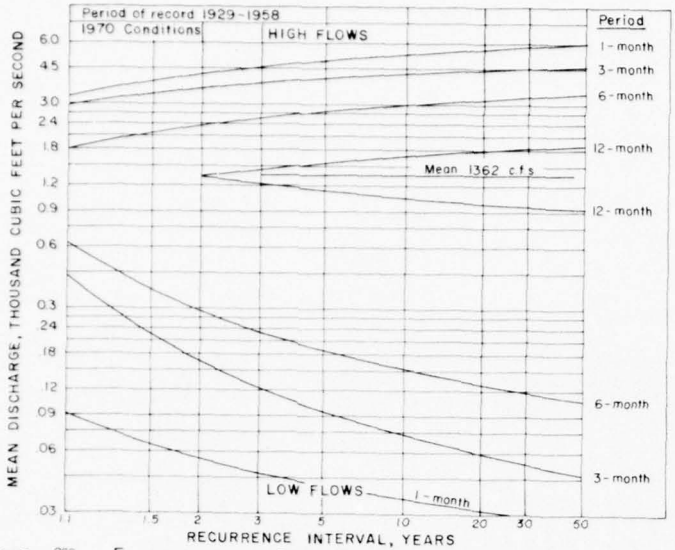


Figure 269 Frequency curves, Snake River near Moran, Wyoming.

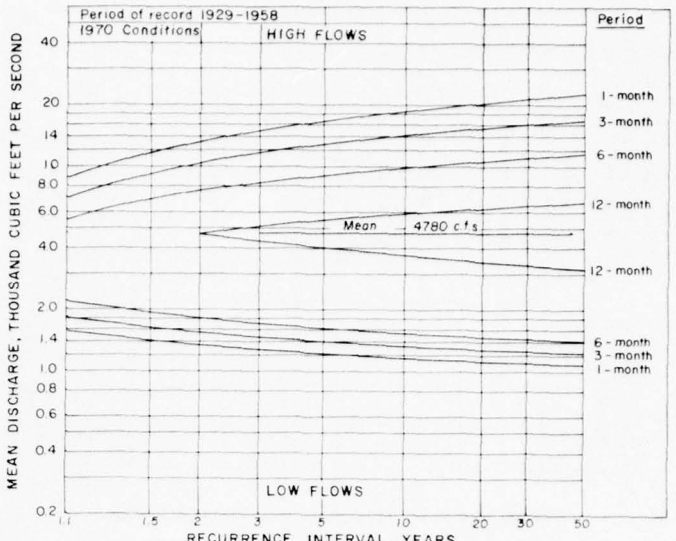


Figure 270 Frequency curves, Snake River at Idaho-Wyoming State Line

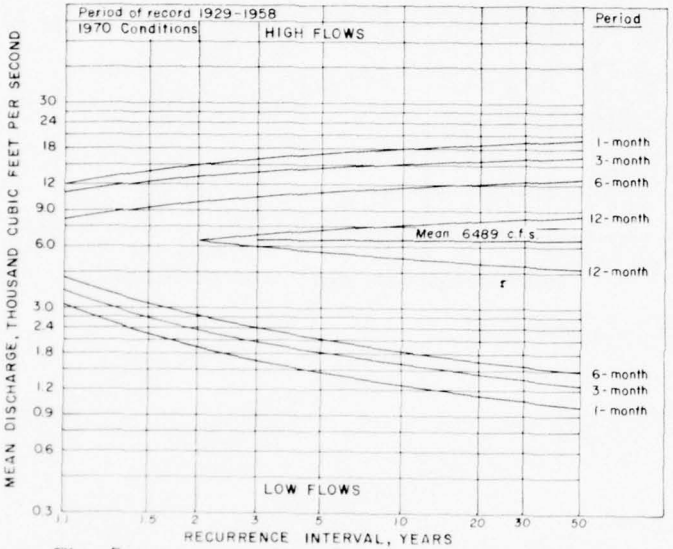


Figure 271 Frequency curves, Snake River near Heise, Idaho.

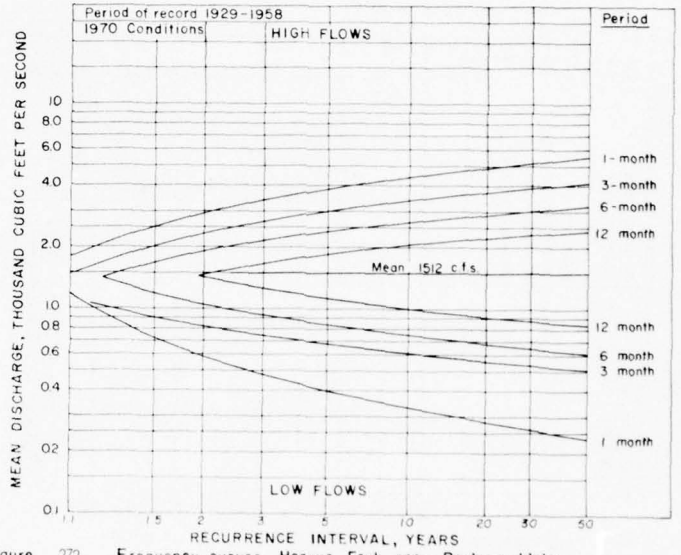


Figure 272 Frequency curves, Henrys Fork near Rexburg, Idaho.

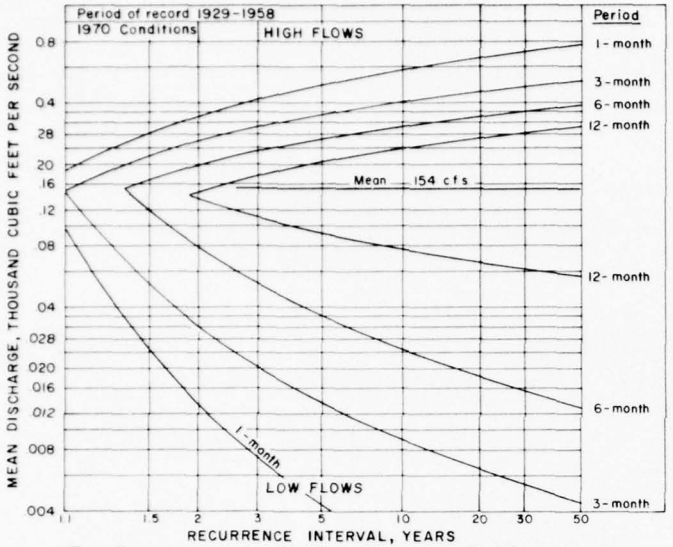


Figure 273 Frequency curves, Blackfoot River near Blackfoot, Idaho

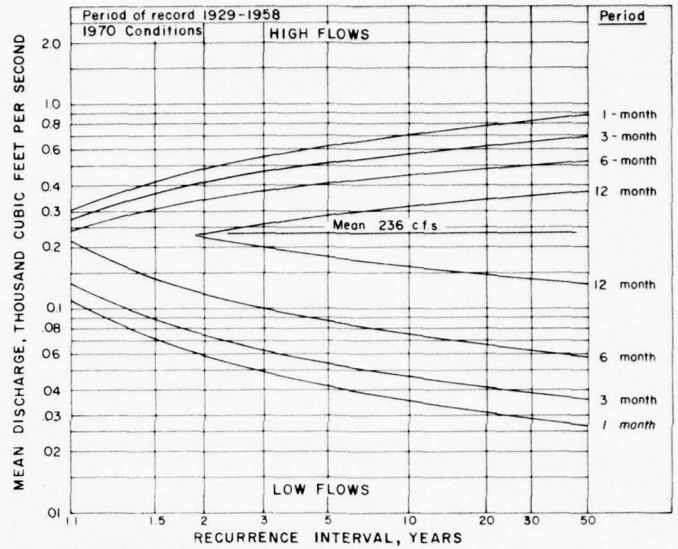


Figure 274 Frequency curves, Portneuf River at Pocatello, Idaho.

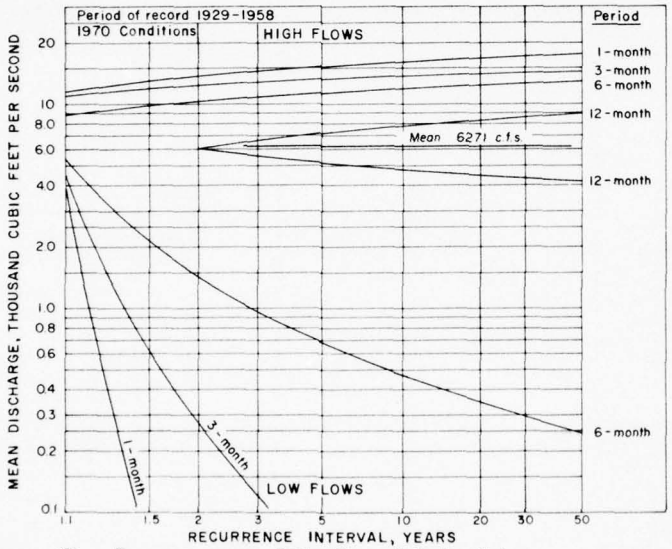


Figure 275 Frequency curves, Snake River at Neeley, Idaho.

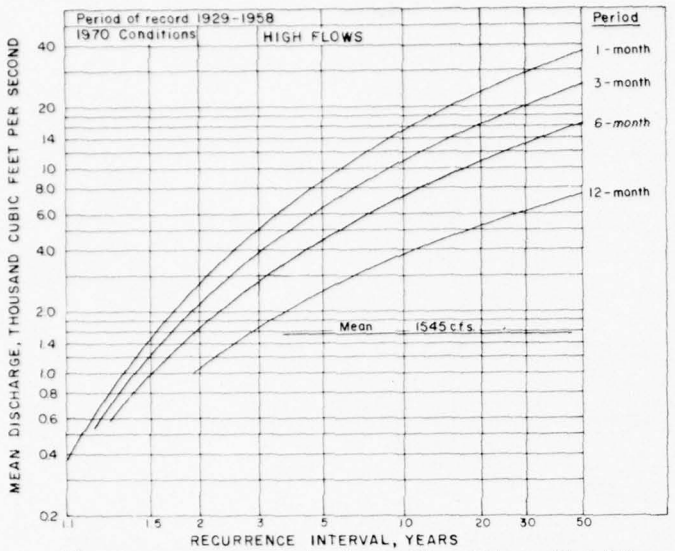


Figure 276 Frequency curves, Snake River at Milner, Idaho. Sh. 1 of 2

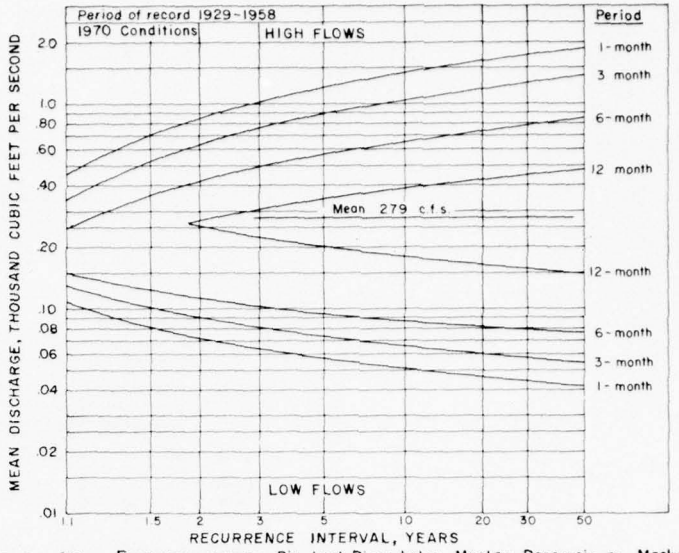


Figure 277 Frequency curves, Big Lost River below Mackay Reservoir nr. Mackay, Idaho.

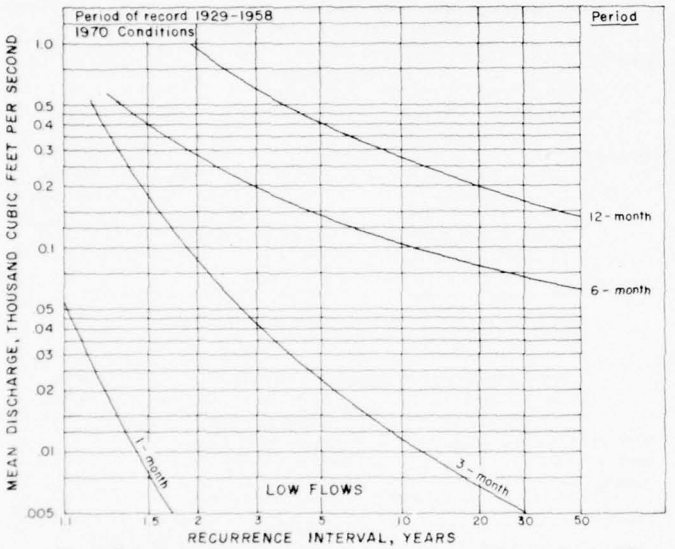


Figure 276 Frequency curves, Snake River at Milner, Idaho Sh. 2 of 2

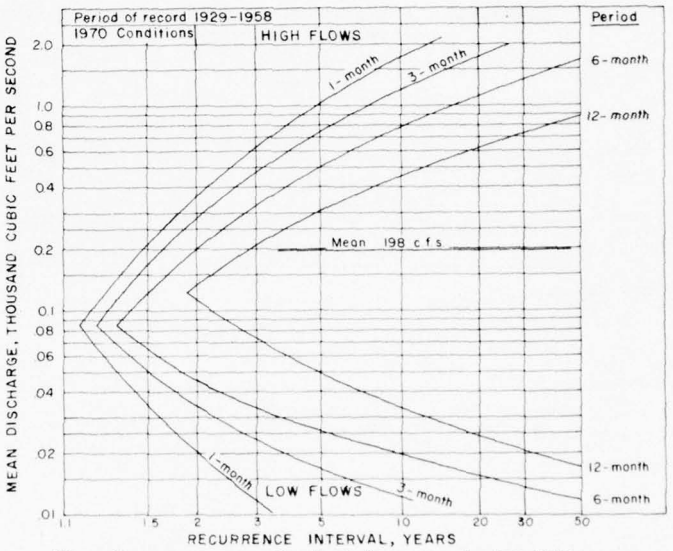


Figure 278 Frequency curves, Big Wood River near Gooding, Idaho.

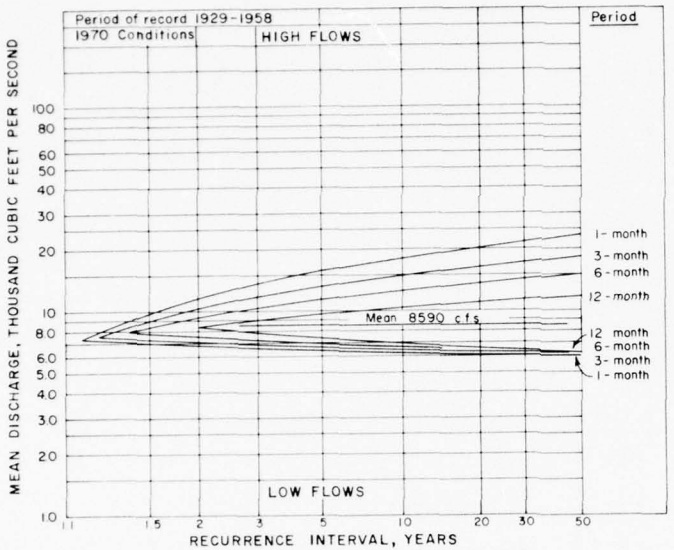


Figure 279 Frequency curves, Snake River at King Hill, Idaho

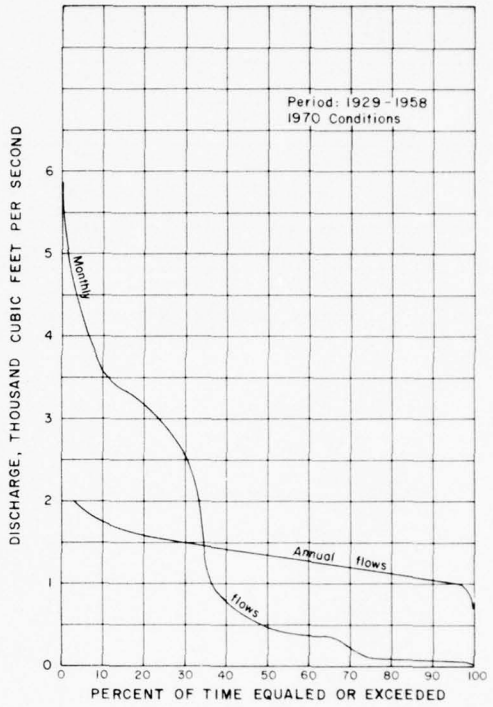


Figure 280 Duration curves, Snake River at Moran, Wyoming

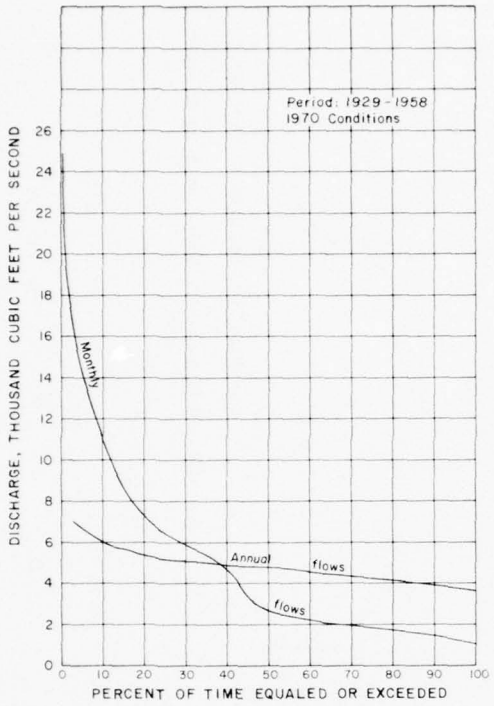


Figure 281 Duration curves, Snake River at Idaho - Wyoming State line.

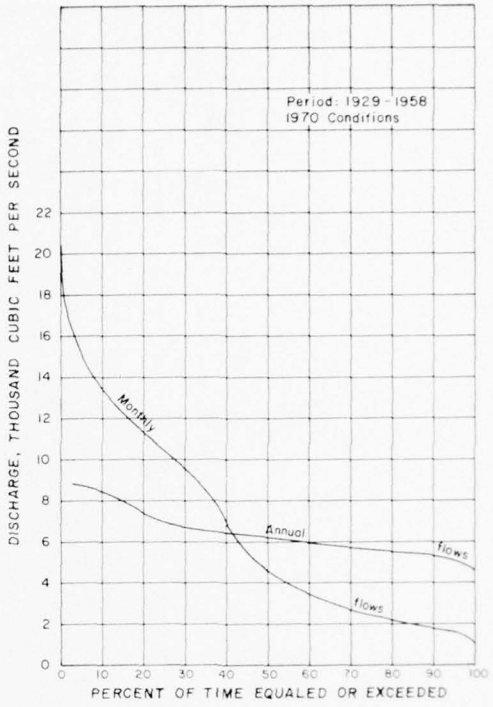


Figure 282 Duration curves, Snake River near Heise, Idaho

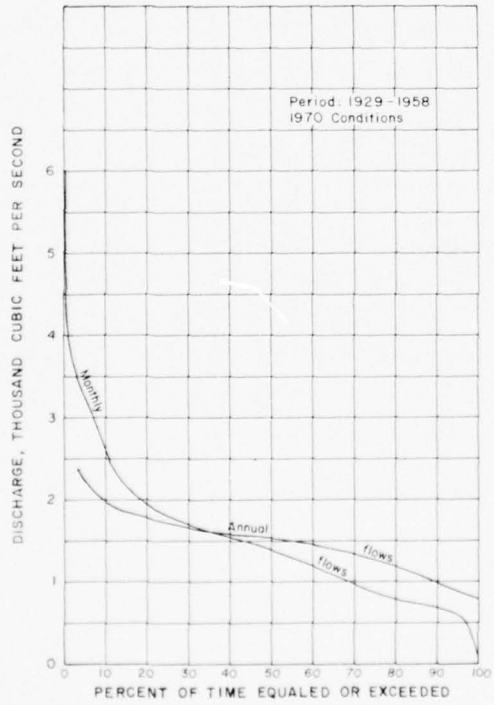


Figure 283 Duration curves, Henrys Fork near Rexburg, Idaho

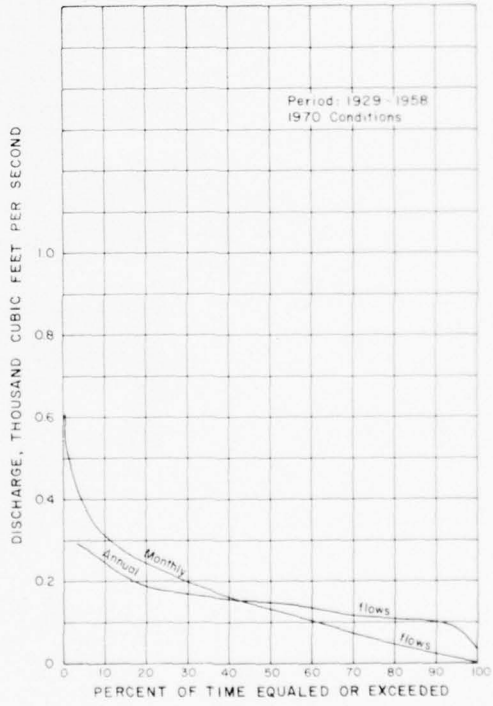


Figure 284 Duration curves, Blackfoot River near Blackfoot, Idaho

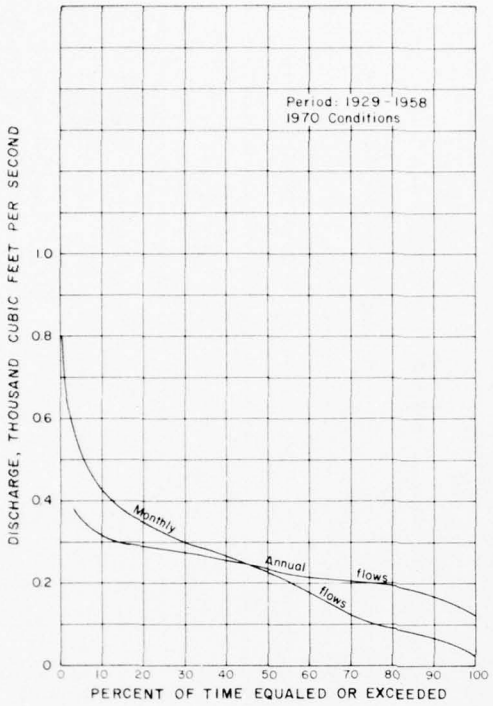


Figure 285 Duration curves, Portneuf River at Pocatello, Idaho

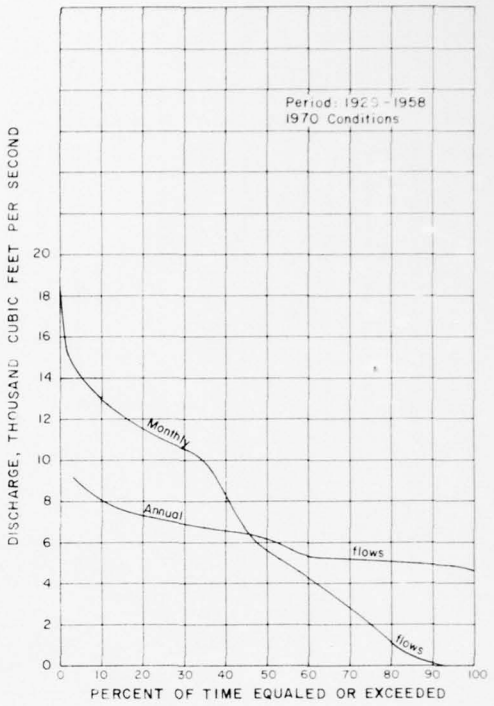


Figure 286 Duration curves, Snake River at Neeley, Idaho

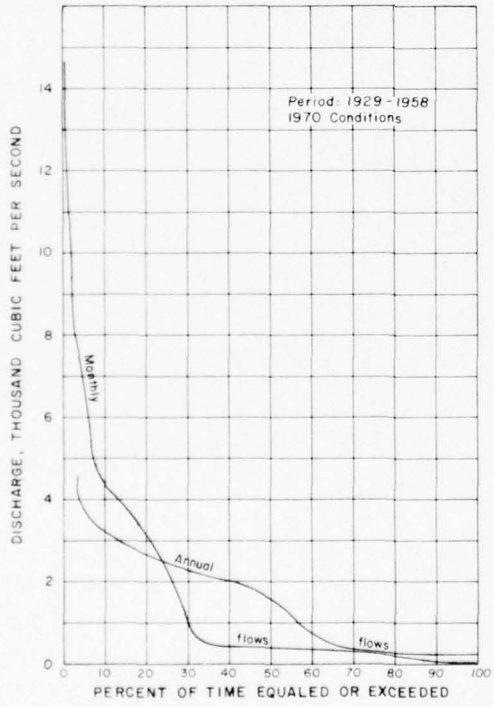


Figure 287 Duration curves, Snake River at Milner, Idaho

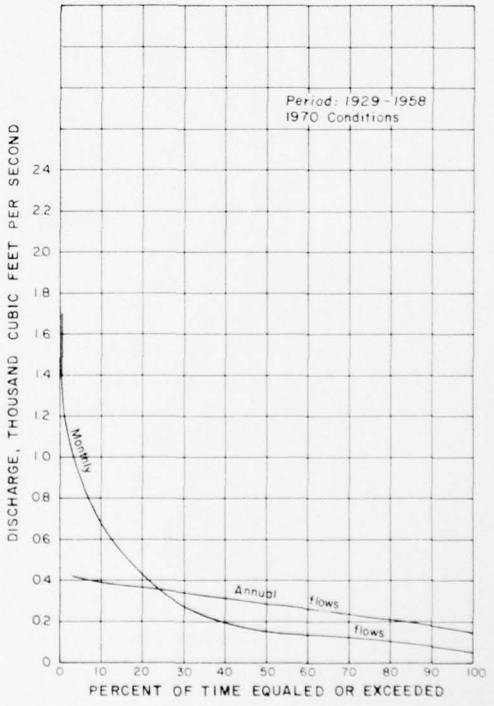


Figure 288 Duration curves, Big Lost River below Mackay Reservoir near Mackay, Idaho

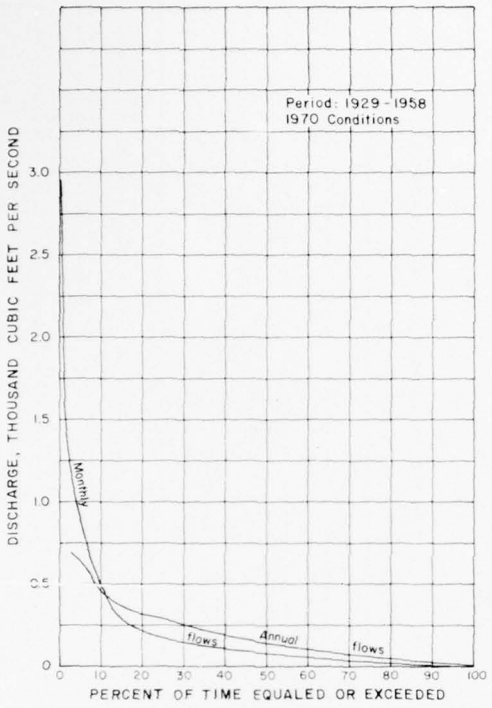


Figure 289 Duration curves, Big Wood River near Gooding, Idaho.

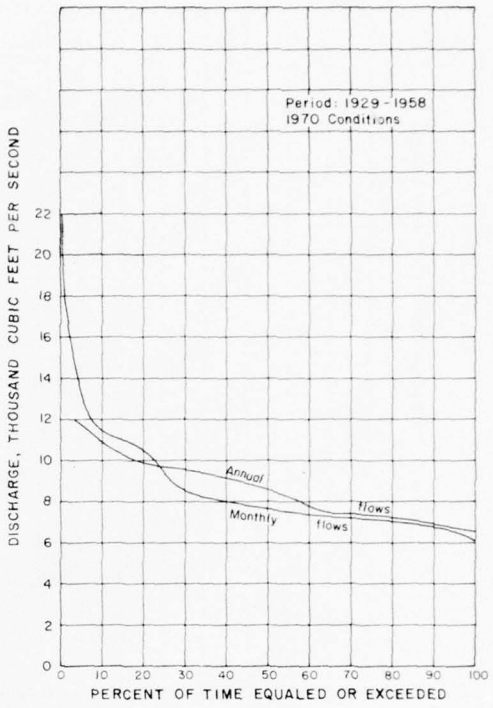


Figure 290 Duration curves, Snake River at King Hill, Idaho

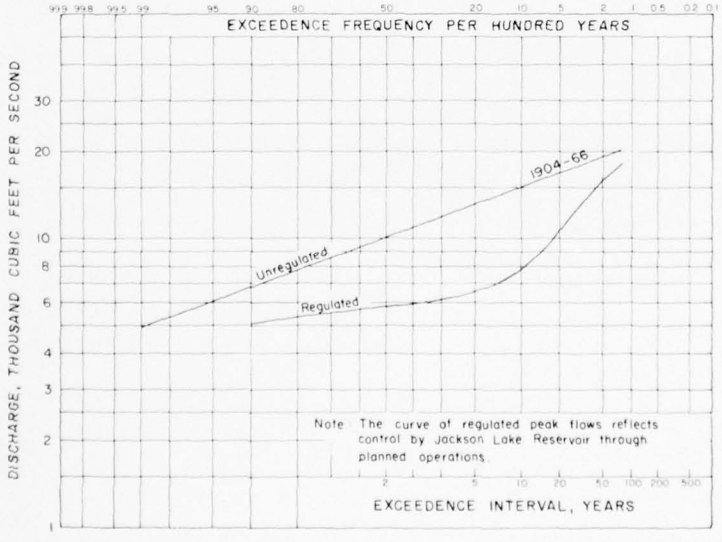


Figure 291 Frequency curve of annual peak flows, Snake River at Moran, Wyoming

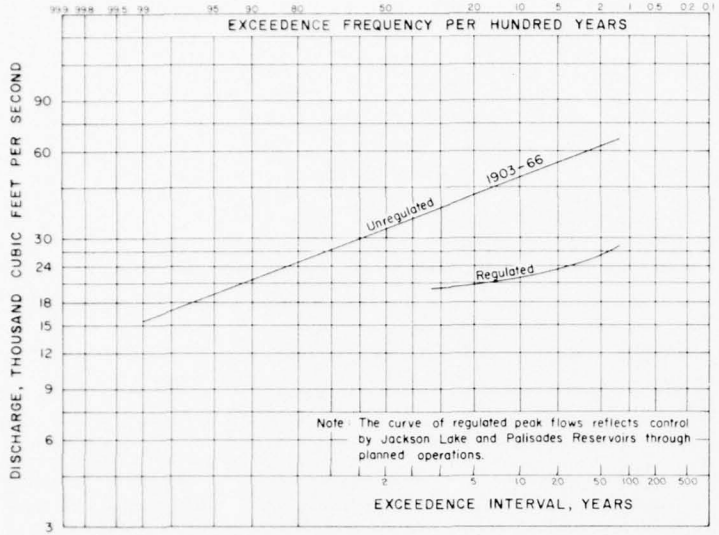


Figure 282 Frequency curve of annual peak flows, Snake River near Heise, Idaho

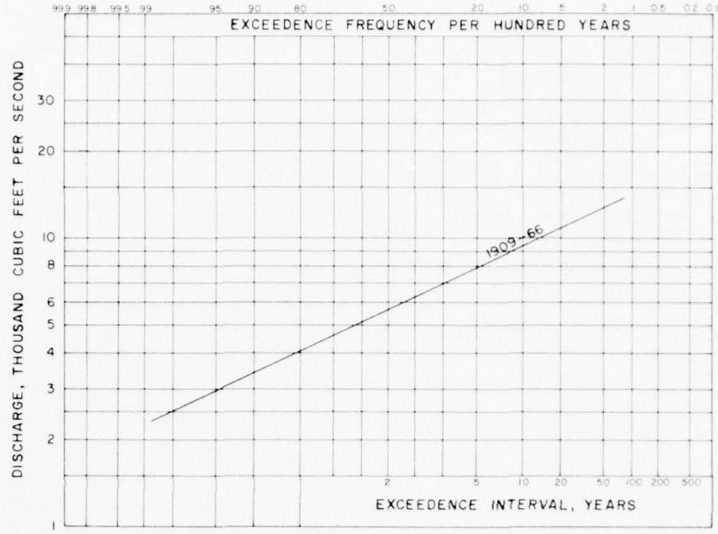


Figure 283 Frequency curve of annual peak flows, Henrys Fork nr. Rexburg, Idaho

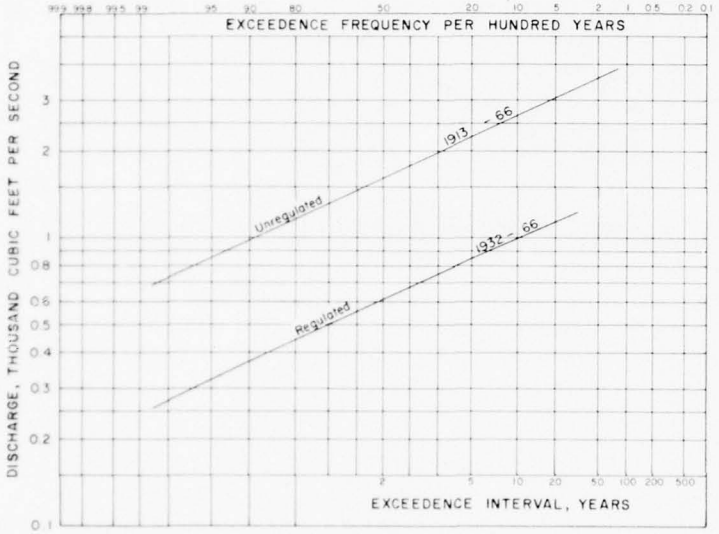


Figure 284 Frequency curve of annual peak flows, Blackfoot R. nr. Blackfoot, Idaho

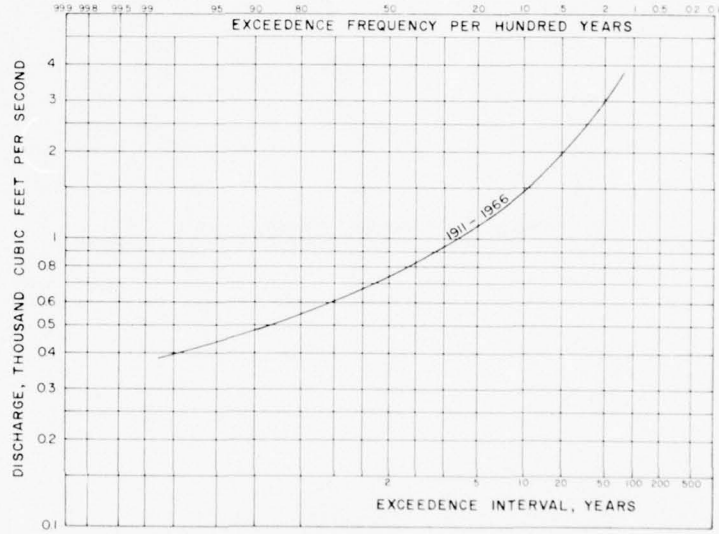


Figure 285 Frequency curve of annual peak flows, Portneuf R. at Pocatello, Idaho

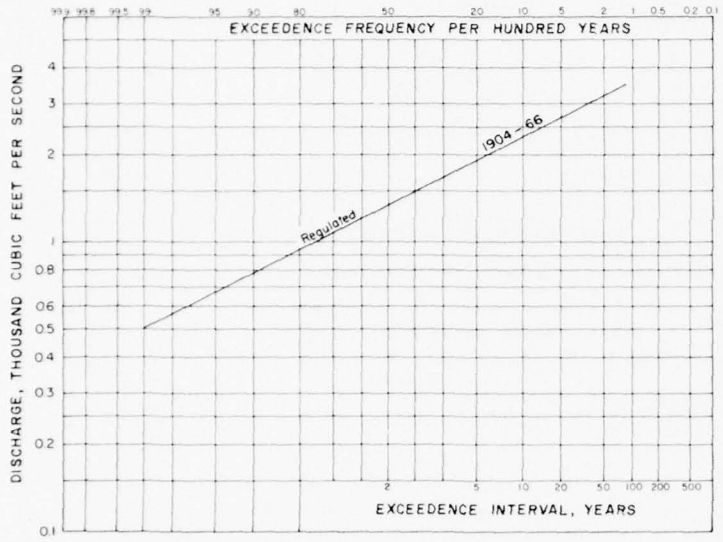


Figure 296 Frequency curve of annual peak flows, Big Lost River near Mackay, Idaho

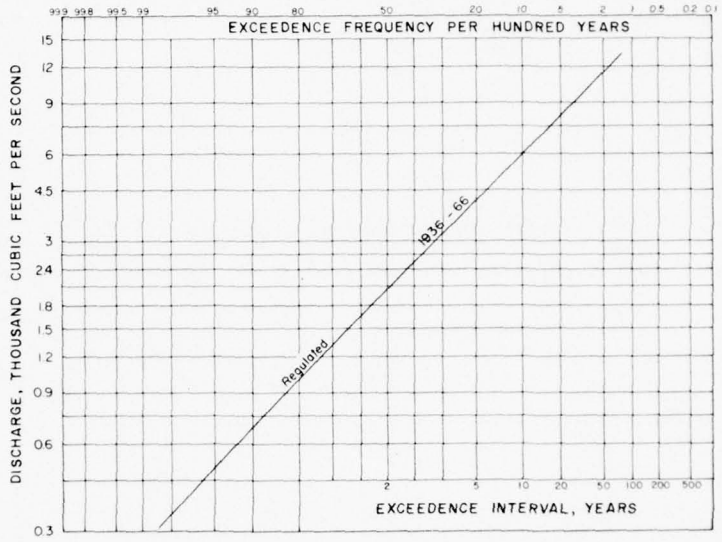


Figure 297 Frequency curve of annual peak flows, Big Wood R. nr. Gooding, Idaho

Table 154. Dependable Yield, Snake River at Moran, Wyoming

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1938	995	73.0
2	1938-39	1,115	81.9
3	1932-34	1,148	84.3
4	1933-36	1,145	84.1
5	1932-36	1,159	85.1
6	1933-38	1,161	85.2
7	1932-38	1,168	85.8
8	1932-39	1,177	86.4
9	1930-38	1,196	87.8
10	1930-39	1,200	88.1
30	1929-58	1,362	100.0

Table 155. Dependable Yield, Snake River at Idaho-Wyoming State Line

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	2,980	62.3
2	1933-34	3,543	74.1
3	1933-35	3,762	78.7
4	1931-34	3,842	80.4
5	1931-35	3,914	81.9
6	1930-35	3,986	83.4
7	1929-35	4,044	84.6
8	1930-37	4,161	87.1
9	1933-41	4,172	87.3
10	1933-42	4,173	87.3
30	1929-58	4,780	100.0

Table 156. Dependable Yield, Snake River near Heise, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	4,765	73.4
2	1933-34	5,186	79.9
3	1933-35	5,346	82.4
4	1932-35	5,421	83.5
5	1931-35	5,472	84.3
6	1931-36	5,586	86.1
7	1931-37	5,605	86.4
8	1931-38	5,619	86.6
9	1934-42	5,642	86.9
10	1933-42	5,639	86.9
30	1929-58	6,489	100.0

Table 157. Dependable Yield, Henrys Forks near Rexburg, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1935	798	52.8
2	1935-36	930	61.5
3	1934-36	976	64.6
4	1934-37	1,014	67.1
5	1931-35	1,043	69.0
6	1931-36	1,046	69.2
7	1930-36	1,051	69.5
8	1930-37	1,061	70.2
9	1930-38	1,092	72.2
10	1929-38	1,137	75.2
30	1929-58	1,512	100.0

Table 158. Dependable Yield, Blackfoot River near Blackfoot, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1935	41	26.6
2	1934-35	74	48.0
3	1933-35	83	53.9
4	1932-35	85	55.2
5	1931-35	90	58.4
6	1932-37	92	59.7
7	1931-37	94	61.0
8	1930-37	102	66.2
9	1929-37	108	70.1
10	1931-40	108	70.1
30	1929-58	154	100.0

Table 159. Dependable Yield, Portneuf River at Pocatello, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	118	50.0
2	1934-35	136	57.6
3	1933-35	161	68.2
4	1932-35	174	73.7
5	1931-35	173	73.3
6	1930-35	176	74.6
7	1930-36	182	77.1
8	1930-37	185	78.4
9	1930-38	191	80.9
10	1931-40	190	80.5
30	1929-58	236	100.0

Table 160. Dependable Yield, Snake River at Neeley, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	4,545	72.5
2	1934-35	4,728	75.4
3	1933-35	4,846	77.3
4	1934-37	4,816	78.4
5	1934-38	4,936	78.7
6	1933-38	4,963	79.1
7	1932-38	4,995	79.6
8	1931-38	5,020	80.0
9	1930-38	5,083	81.0
10	1933-42	5,097	81.3
30	1929-58	6,271	100.0

Table 161. Dependable Yield, Snake River at Milner, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1938	244	15.8
2	1937-38	248	16.0
3	1931-33	267	17.3
4	1931-34	272	17.6
5	1931-35	281	18.2
6	1933-38	288	18.6
7	1932-38	287	18.6
8	1931-38	282	18.2
9	1930-38	334	21.6
10	1931-40	388	25.1
30	1929-58	1,545	100.0

Table 162. Dependable Yield, Big Lost River below Mackay Reservoir near Mackay, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	128	45.9
2	1933-34	168	60.2
3	1934-36	184	65.9
4	1934-37	179	64.2
5	1933-37	185	66.3
6	1931-36	196	70.2
7	1931-37	192	68.8
8	1930-37	196	70.2
9	1929-37	195	69.9
10	1929-38	211	75.6
30	1929-58	279	100.0

Table 163. Dependable Yield, Big Wood River near Gooding, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	21	10.6
2	1934-35	27	13.6
3	1929-31	30	15.2
4	1929-32	32	16.2
5	1931-35	35	17.7
6	1930-35	36	17.7
7	1929-35	35	17.7
8	1929-36	39	19.7
9	1929-37	41	20.7
10	1929-38	83	41.9
30	1929-58	198	100.0

Table 164. Dependable Yield, Snake River at King Hill, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1935	6,909	80.4
2	1931-32	6,966	81.1
3	1931-33	6,977	81.2
4	1932-35	6,978	81.2
5	1931-35	6,976	81.2
6	1931-36	7,002	81.5
7	1931-37	6,998	81.5
8	1931-38	7,012	81.6
9	1930-38	7,099	82.6
10	1931-40	7,124	82.9
30	1929-58	8,590	100.0

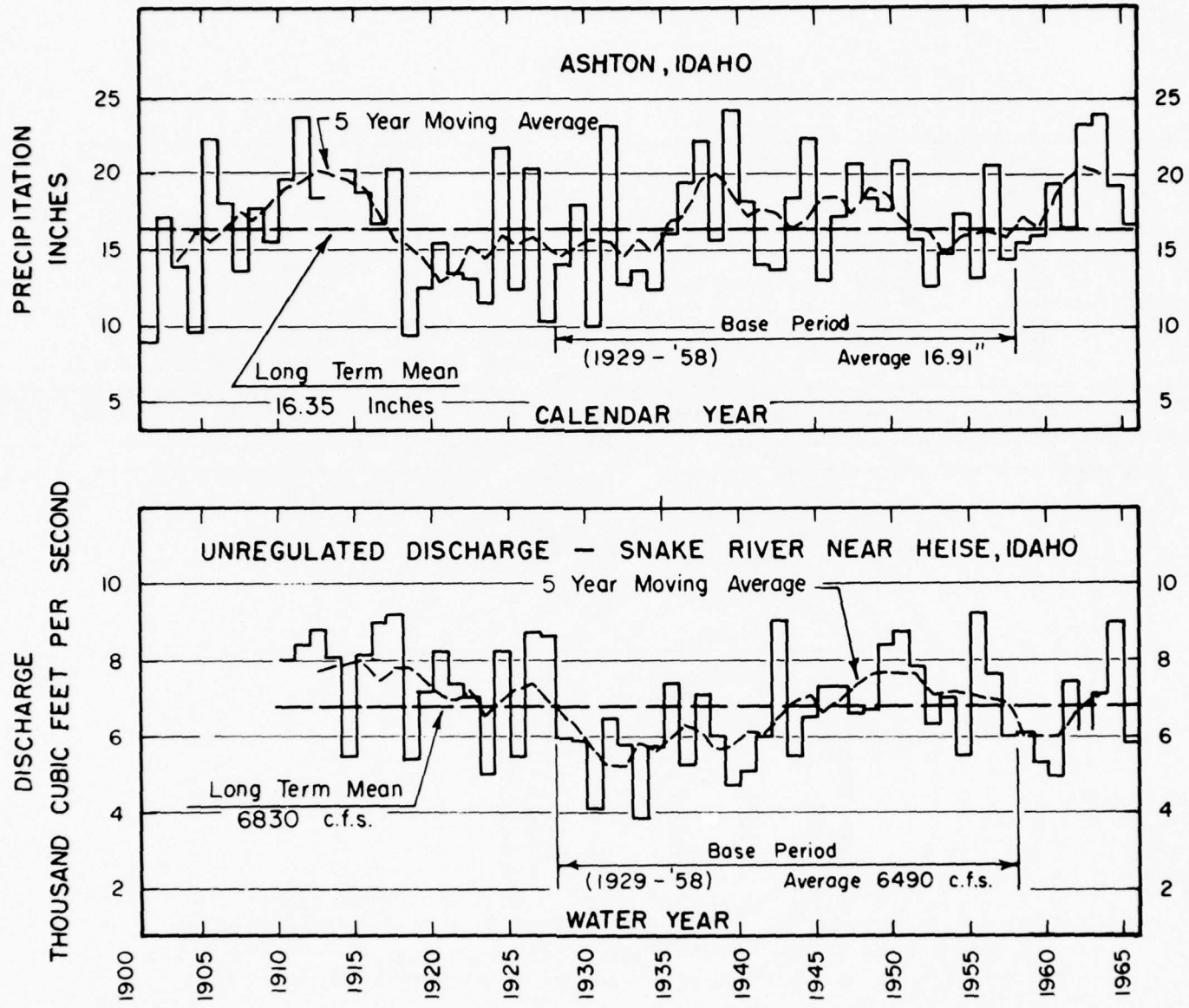


Figure 298 Long-term variation in precipitation and streamflow.

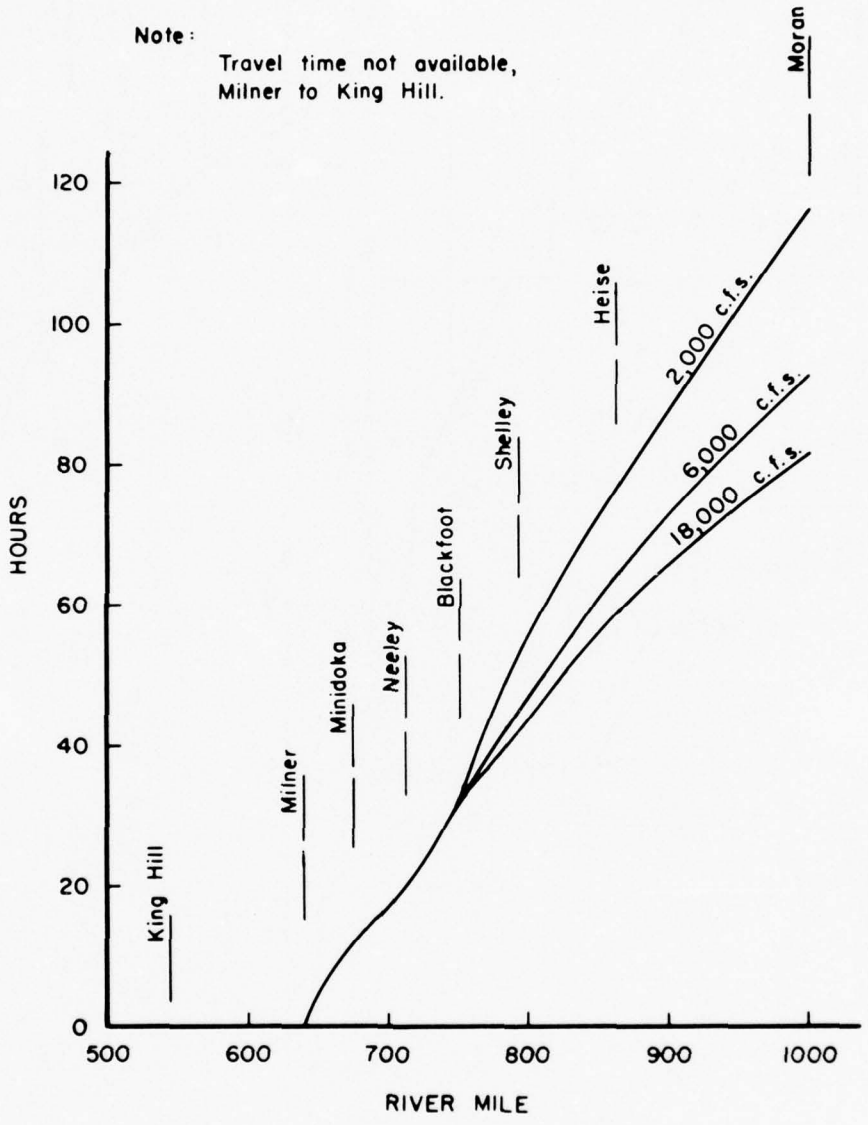


Figure 299 Time of travel, Snake River - Moran to Milner, for selected discharges at index gaging stations.

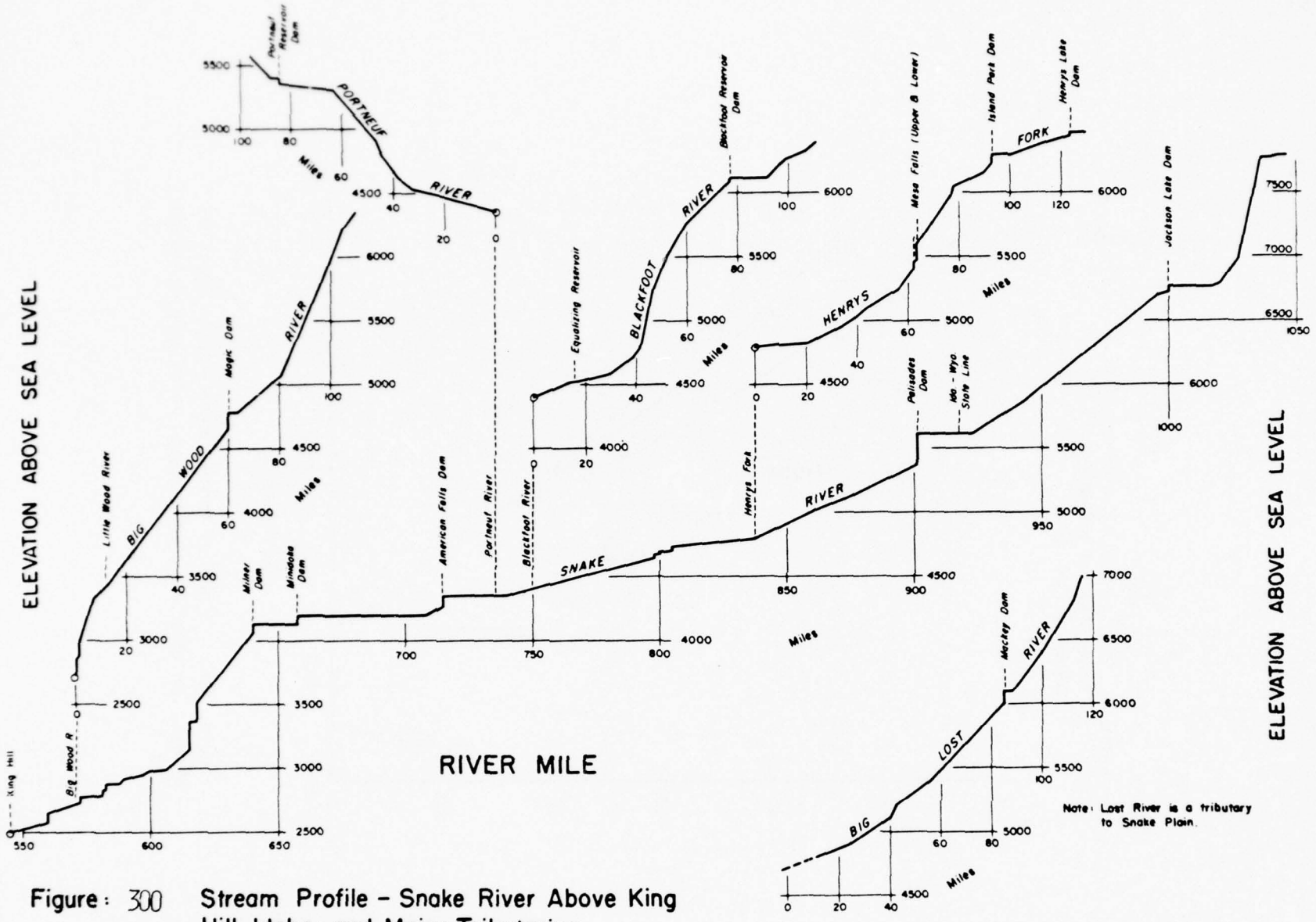


Figure: 300 Stream Profile – Snake River Above King Hill, Idaho; and Major Tributaries.

Quality

The following sections discuss aspects of the quality of the surface waters of the Upper Snake Subregion; water quality is discussed under these topics: chemical, biochemical-biological, sediment, and water temperature.

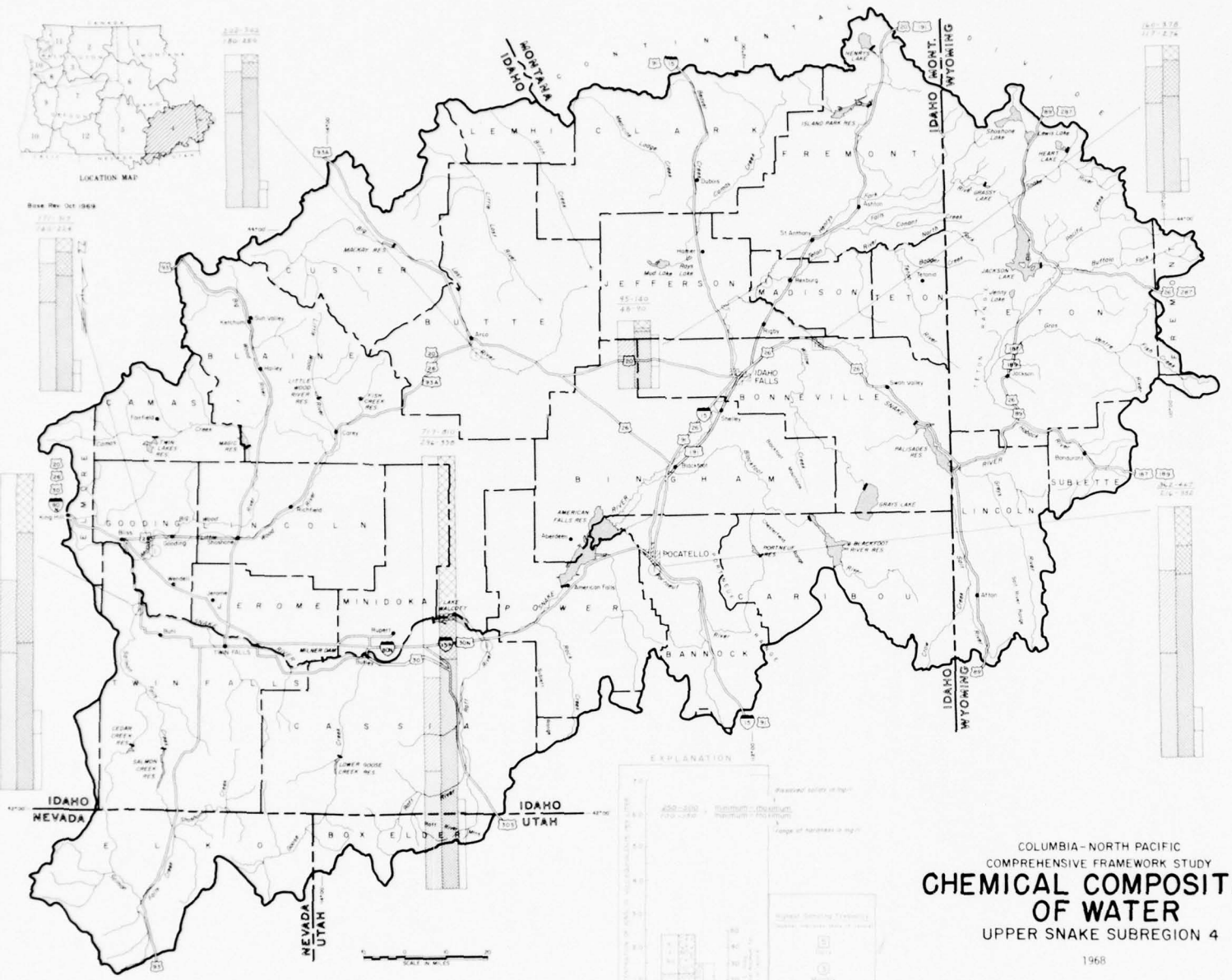
Chemical

Streamflows near the source of most tributaries in the Upper Snake Subregion are relatively dilute calcium bicarbonate type waters, having 100 mg/l (milligrams per liter) or less of dissolved solids. However, dissolved solids and sodium content show marked increases as the water proceeds downstream. The dissolved solids content of some streams as they enter the Snake River is as much as seven times greater than that in their headwaters area. (64-1)

Tributaries entering the Snake River from the south are usually more highly mineralized and have larger percentages of sodium, chloride, and sulfate. The higher concentrations are due partly to percolation of irrigation water through rocks with higher soluble mineral content. A second factor is the smaller amount of precipitation in the headwaters area of the southern portion of the basin. The lower rainfall results in less runoff being available for dilution. Also, more soluble materials are available to increase mineral concentration because less material has been leached from the soils by precipitation. (figure 301)

The main stem of the Snake River shows downstream changes in chemical quality which reflect both man's use and the effects of waters of different natural quality entering the stream. Samples collected during a low-flow period in 1965 in the reach from Alpine, near the Idaho-Wyoming border, to Buhl, Idaho, showed a progressive increase in both dissolved solids concentration and SAR (sodium-adsorption ratio). Dissolved solids increased from about 175 to more than 400 mg/l, and SAR increased from 0.2 to 1.5 mg/l. (73) Below Buhl, the dissolved solids concentration dropped to 340 mg/l because of dilution by spring inflow. The alluvial materials in the area contribute to this downstream increase in mineral content of the main stem as also do irrigation return flows. In some areas, treatment is required before the water can be used as a municipal or industrial supply.

In parts of the Henrys Fork Basin, unusually high concentrations of fluoride occur. Laird (64-14) reports concentrations of more than 4.0 mg/l in places. Big Springs Creek, Buffalo River, Warm River, and Falls River contained more than 2.0 mg/l fluoride in August 1960. Henrys Fork, from Island Park Reservoir to the mouth, contained from 1.4 to 1.8 mg/l. The higher fluoride concentrations occur in streams draining the volcanic formations in the northern and eastern parts of the basin. (64)



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

CHEMICAL COMPOSITION OF WATER

UPPER SNAKE SUBREGION 4

1968

FIGURE 301

Biochemical-Biological

Dissolved oxygen levels of the Upper Snake River and its tributaries are usually near the saturation level, as indicated in table 165. However, reduced dissolved oxygen concentrations have at times been a problem on the main stem of the Snake River within the subregion, particularly in Milner Lake. Milner Lake is a pool over 30 miles long created by Milner Dam, located some 10 miles west of the town of Burley. The most serious pollution problem has occurred in the downstream portion of the pool below Burley. This pollution, which is largely a winter problem, is caused by several factors: in recent years, potato and sugar processors have been discharging large quantities of oxygen-demanding wastes into the river; some municipal wastes are discharged into the river in this reach; at times during the winter very little water is passing through the pool because it is being stored in fulfillment of upstream rights; and, when the pool becomes ice covered, reaeration is inhibited. Because of these factors, the pool becomes septic at times; among other adverse effects, this pollution has caused some of the most severe rough fish kills in the United States in a few given years.

In August 1967, very low dissolved oxygen levels in American Falls Reservoir were caused by extremely hot weather, low water levels in the reservoir, discharges of inadequately treated wastes, and the sudden death and decay of a large mass of algae collected at the western end by wind action. As a result, a substantial number of game and trash fish were killed.

Table 165 - Dissolved Oxygen & Coliform Organisms Densities
Upper Snake Subregion

Location	Dissolved Oxygen mg/l			Coliform Organisms /100 ml		
	Mean	Min	Max	Mean	Min	Max
Snake R. at Lorenzo	9.7	7.6	11.9	398	109	542
Henrys Fork nr St. Anthony	10.5	8.9	12.1	-	-	-
N. F. Teton R. nr Sugar	10.8	9.2	12.3	-	-	-
S. F. Teton R. nr Rexburg	10.3	8.3	12.0	-	-	-
Henrys Fork nr Rexburg	8.4	6.5	10.8	1,065	141	1,600
Snake R. above Idaho Falls	9.4	7.6	11.4	-	-	-
Snake R. nr Shelly	9.8	8.0	11.9	-	-	-
Blackfoot R. at mouth	9.2	6.9	10.7	-	-	-
Snake R. at Tilden Bridge	9.7	6.9	11.8	25,400	16,000	34,800
Portneuf R. nr mouth	7.4	5.3	9.5	-	-	-
Snake R. below Amer. Falls	9.0	6.5	12.8	5,403	70	16,000
Raft R. nr mouth	9.6	1.9	13.7	9,725	3,450	16,000
Snake R. at Milner Dam	7.8	3.6	9.8	14,608	2,210	34,800
Snake R. nr Hagerman	9.3	8.1	10.0	3,180	1,600	5,420

The biological quality of the Snake River is variable. High bacterial concentrations are found in the reaches below Idaho Falls and below Burley; these concentrations are caused both by industrial wastes and by inadequately treated municipal sewage.

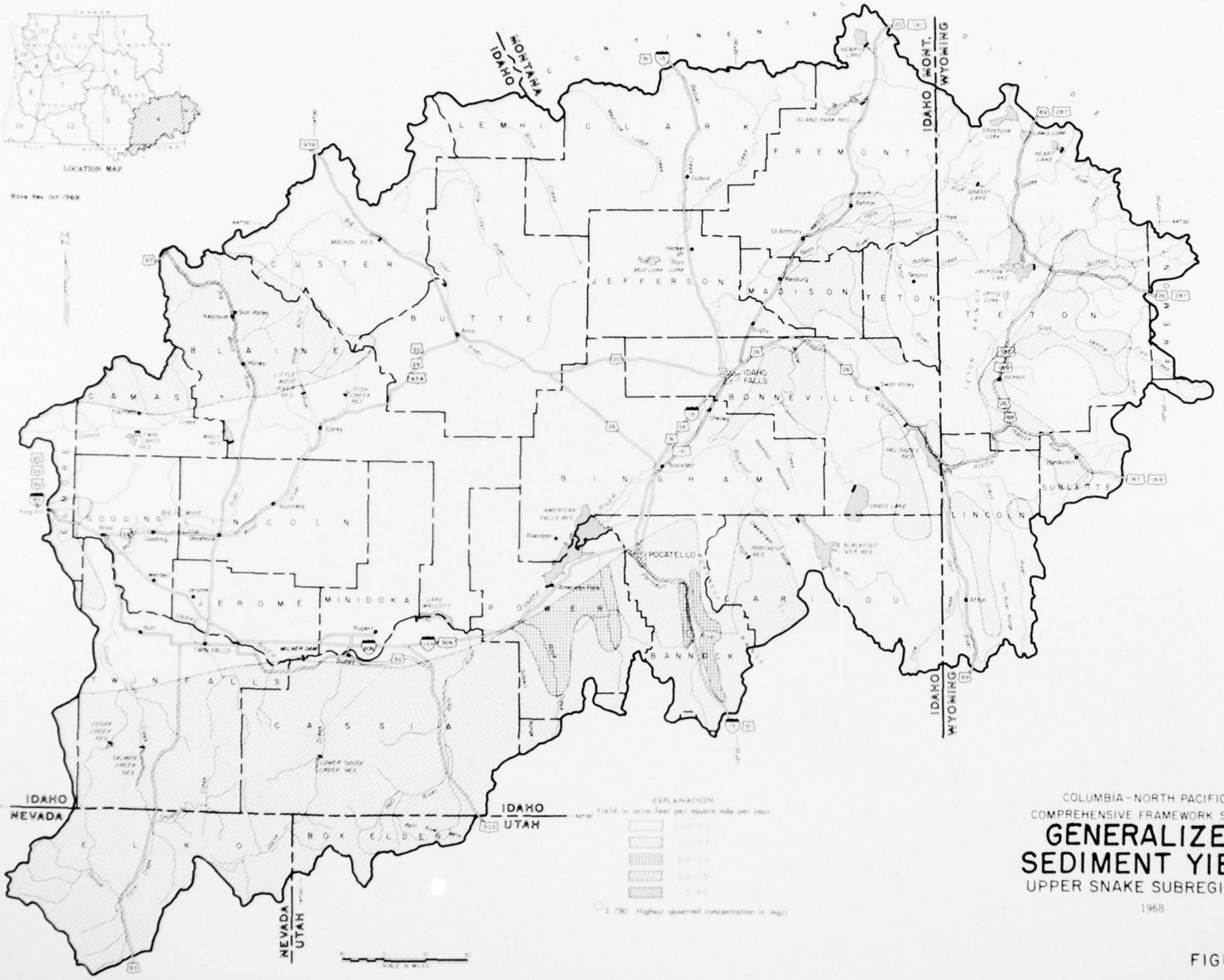
Densities of coliform organisms below some populated areas are high enough that the water is considered unsuitable for water-contact recreation. For example, table 165 shows very low densities of coliform organisms in the upper reaches of the Henrys Fork and the Snake River; however, below Idaho Falls and Shelly (as measured at Tilden Bridge just above American Falls Reservoir) and below Burley (as measured at Milner Dam), the densities are often quite high.

Sediment

The few suspended-sediment concentration data (all unpublished) available for the Upper Snake Subregion were collected intermittently during the period 1943-60. Reconnaissance-type studies of sediment deposition in three small reservoirs in Gooding and Blaine Counties were made in 1954. A low rate of sediment yield was indicated by these studies. Figure 301A shows that sediment yield ranges between 0.02 and 0.5 acre-foot per square mile per year. (30) Most of the Snake River Plain yields less than 0.1 acre-foot per square mile per year, and only one small area south of American Falls exceeds 0.2. In the smaller watersheds on the north side of the Snake River Plain, much of the coarse sand and gravel is presumably derived from channel and bank erosion. Actual sediment contributions from much of the area of southern Idaho are unknown.

Water Temperature

Water temperature data are published by the Geological Survey for three sites in the subregion. These data are not sufficient to develop an adequate stream temperature profile, although they do give an indication of the magnitude and variation of temperatures at the measuring points. Temperatures and chemical quality data are published for the Snake River near Heise and at King Hill. In addition, temperatures are given for the Henrys Fork near Rexburg. Maximum, minimum, and mean monthly values for varying lengths of record are shown in figure 302.



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GENERALIZED SEDIMENT YIELD

UPPER SNAKE SUBREGION 4

1968

FIGURE 301 A

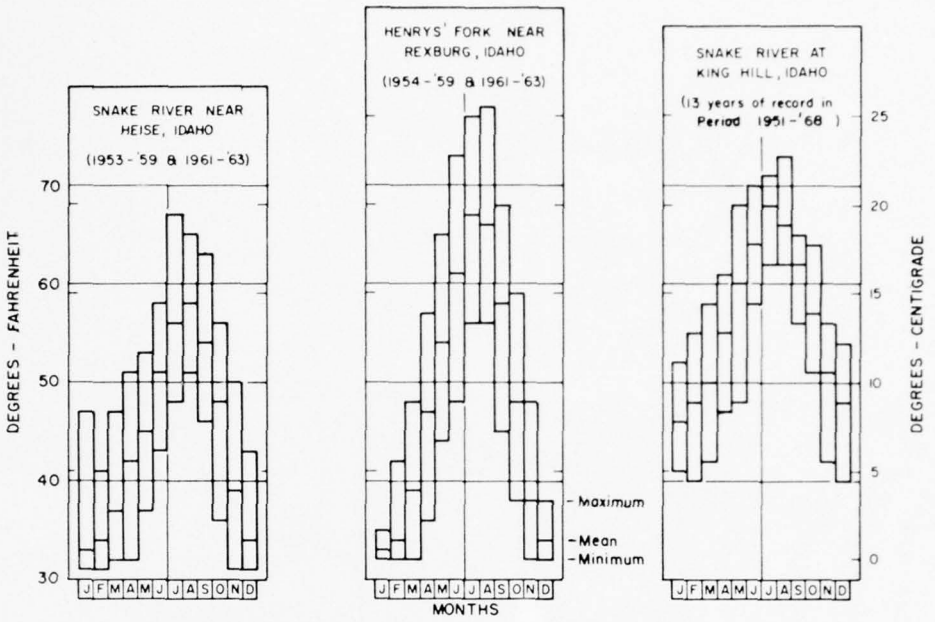


Figure 302 Monthly water temperatures for selected stations.

GROUND WATER

Two aquifer units, the alluvial deposits (Qal) of Quaternary age and the basaltic volcanic rocks of late Tertiary and Quaternary age (QTv), are major aquifers in Subregion 4. These aquifers, especially the volcanic rocks, support the most extensive ground-water development in the entire region. A third aquifer unit, the silicic volcanic rocks (Tsv), sustains considerable local ground-water development. A fourth unit, the sedimentary deposits of late Tertiary and early Quaternary age (QTs), also yields moderate to moderately large amounts of water at some places.

The chemical quality of the water generally is good to excellent. Dissolved solids are usually less than 500 mg/l. Water from the silicic volcanic rocks has a high sodium percentage at some locations.

Many reports have been released giving information on aquifers and occurrence of ground water in various parts of Subregion 4. The more significant ones are listed in references 21, 25, 26, 31, 57, 81, 85, 86, 88, 93, 146, 149, 150, 183, 192, 203.

Aquifer Units and Their Hydrologic Characteristics

Seven aquifer units have been delineated in Subregion 4. Aquifer units are shown in figure 303, which is based chiefly on the geologic map of Idaho (133), Wyoming (69), Utah (154), and Nevada (156).

The alluvial and associated deposits of Quaternary age (Qal) include stream alluvium forming terraces and benches and underlying flood plains; glacial outwash, till, and undifferentiated glacial drift; and lacustrine deposits of silt and fine sand. Some of the older gravel deposits are interbedded with basalt flows of the Snake River group. (72) Coarse sand and gravel deposits are extensive in the alluvial aquifer units along the Snake River and its major tributaries; the deposits are very porous and permeable and yields of one to several thousand gallons per minute are common.

The basaltic lava of late Tertiary and Quaternary age (QTv) belongs chiefly to the Snake River group, but includes some lava of the Idaho group. (72) The lavas and interbedded pyroclastics and sedimentary materials underlying the Snake River Plain east of Bliss compose the Snake Plain aquifer (86), one of the most productive in the United States. Generally, individual flows range from 10 to 50 feet in thickness and probably average 20 to 25 feet. Typically, the central part of an individual flow has low permeability. The results of laboratory tests on 83 core samples gave an average permeability of 0.14 gallons per day per square foot. (86-158) However, the upper surfaces of most flows are irregular and they may be very rough and blocky. Lava of overlying flows generally fails to completely fill these openings, resulting in very permeable interflow zones. Scoria, coarse cinders, or gravel may be interbedded with the lavas and also are good aquifers; however, silt or clay interbeds greatly reduce the permeability. Transmissibilities determined from 33 pumpage tests in the Snake Plain aquifer averaged 5 million gallons a day per foot. (86-158) Most of these tests were made on wells penetrating 75 to 200 feet below the water table and did not represent the entire thickness of the aquifer unit.

Not all of the younger volcanic rocks (QTv) shown on figure 303 are as permeable as the Snake Plain aquifer. Basalt south of the Snake River in the Twin Falls-Salmon Falls area is somewhat older, probably belonging chiefly to the Idaho group. (72) The coefficient of transmissibility of the basalt and silicic volcanic rocks (Tsv) in the Salmon Falls area was estimated by Fowler (31-12) to average about 15,000 gallons per day per foot.

The sedimentary deposits of late Tertiary and Quaternary age (QTs) include sediments of the Snake River group, the Idaho group, the Salt Lake formation, and Pliocene and Miocene sediments in Wyoming. These range mostly from Pliocene to Middle Pleistocene in age, but the Salt Lake formation may include some older deposits. Over large areas the deposits consist predominantly of fine-grained materials--silt, bedded tuff, clay, and fine sand. Pyroclastic materials and lava flows are interbedded with the sediments in both the Idaho group and the Salt Lake formation and these materials, with occasional lenses of coarse sand or gravel, are more permeable and produce moderate yields locally.

The silicic volcanic rocks of Tertiary age (Tsv), mostly Pliocene, are chiefly welded tuff and latitic and rhyolitic flows, but include bedded tuff and some gravel beds. Silicic volcanic rocks interfinger with the Salt Lake formation in eastern Idaho and in many areas the relations between the two units have not been well defined. In the western part of Subregion 4 these rocks have been mapped as the Idavada volcanics (72) of lower Pliocene age. The hydrologic characteristics of the silicic volcanic rocks vary greatly. At some places only small to moderate yields can be obtained; at other places, such as on the Rexburg Bench, and at several locations in the Goose Creek-Dry Creek area and the Salmon Falls Basin, moderately large to large yields are obtained. The larger yields apparently are obtained from wells penetrating coarse pyroclastics or interbedded basaltic volcanic rocks.

The older consolidated sedimentary strata of Tertiary age (Tos) crop out only in Wyoming. They consist of many types of fine to coarse-grained stratified sediments. Much of their primary porosity and permeability has been reduced by compaction and cementation; some secondary porosity has developed from jointing and other fracturing. As a rule, the finer-grained strata will yield only small amounts of water because of low porosity and permeability, but coarser-grained phases may yield larger supplies, especially in areas where faulting has fractured the rocks.

The Challis volcanics (Tcv) consist of a varied assemblage of rocks, chiefly rhyolitic in composition, but they also include some basalt flows, welded tuffs, and pyroclastics. Most of these rocks are believed to range from Eocene to Miocene in age. Generally they are greatly altered and mineralization has reduced their original porosity and permeability. They crop out in large uninhabited areas north of the Snake River Plain and the scanty information available suggests that they usually have low porosity and permeability.

A diverse group of rocks is collectively shown as pre-Tertiary (pT). This unit includes consolidated sedimentary rocks such as shale, limestone, and sandstone and intrusive igneous rocks

such as granite. These form the mountain ranges which are largely uninhabited but they underlie some basins at relatively shallow depths. Most of these rocks have low porosity and permeability and yield only small quantities of water. However, several wells in the western margin of the Goose Creek Basin, and several in Nevada, yield large supplies from pre-Tertiary limestone. Many small springs discharge from the pre-Tertiary aquifer unit and its chief importance is in supplying a large volume of shallow, fairly short-term storage that maintains the base flow of streams draining the mountains.

A summary description of the aquifer units, their general hydrologic characteristics, and the general quality of the water yielded by them are given in table 166. The general availability of ground water is shown on a map, figure 304. For maximum utility, that map and the aquifer-unit map, figure 303, should be used together.

Water in Storage

A rough estimate of the quantity of water stored in each aquifer unit in a specified depth interval below the water table is given in table 167.

The alluvial aquifer unit (Qal) is predominantly coarse grained, but does include some lake bed sediments in several areas. A specific yield of 20 percent was used for this unit.

The younger volcanic rocks (QTv) have high porosity but not all pores are interconnected; therefore, the specific yield probably is considerably less than the porosity. The average coefficient of storage determined in 18 aquifer tests in the Snake Plain aquifer was 4 percent. (86-158) Because these tests were of only a few days' duration, the storage coefficient shown by the tests may be smaller than the true specific yield. A value of 5 percent was used for computing storage for table 167.

The younger Tertiary sedimentary deposits (QTs) are only moderately consolidated and compacted and generally only lightly cemented; therefore, a specific yield of 10 percent was used for computing the volume of water stored for this unit.

The silicic volcanic rocks (Tsv) and the older sedimentary rocks (Tos) were assigned a specific yield value of 2 percent. The Challis volcanics (Tcv) and the pre-Tertiary rocks (pT) probably have very low porosity at depth, perhaps much less than 1 percent. These two units have moderately deep zones of weathering and,

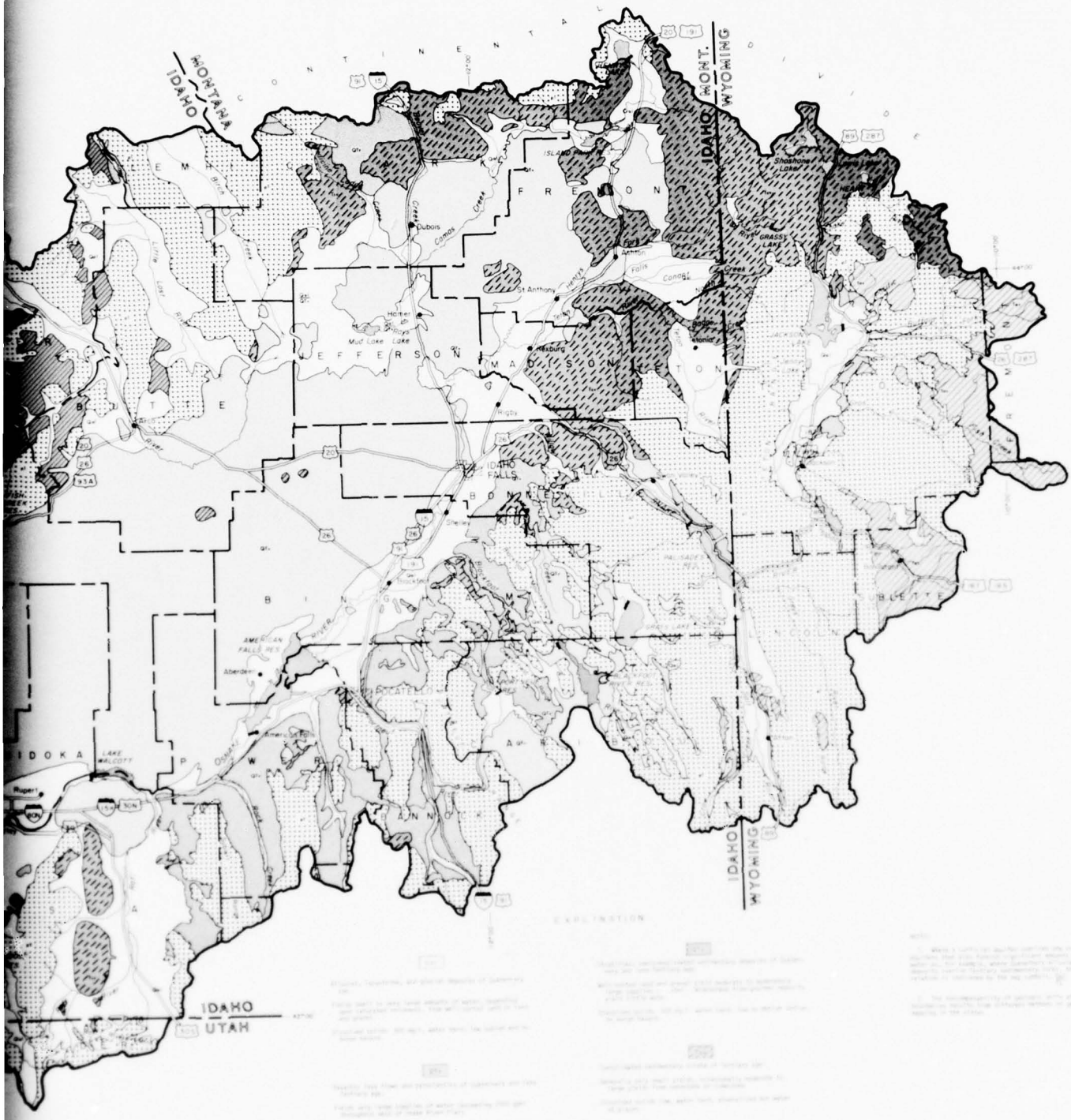
Table 166. Description of Aquifer Units and Their Hydrologic Characteristics, Subregion 4

Map Symbol and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
Qal: *Alluvium, eolian deposits;* glacial drift including outwash deposits; terrace sand and gravel; lake beds and playa deposits. Pleistocene to Holocene in age.	Clay, silt, sand, gravel, and boulders; unconsolidated to semiconsolidated, at places cemented. Alluvium and glacial deposits floor the valleys, and terrace gravel occurs along some streams. Lake beds formed behind basalt dams in Rupert, American Falls, Roberts, Mud Lake, and other areas. Windblown deposits mantle much of area.	Sandy and gravelly alluvium yields moderate to large *quantities of* water to wells. Yields from 50 to 150 feet of saturated coarser material commonly are 1,000-2,500 gpm. Specific capacities are commonly 20 to 100 gpm per foot. Aquifer recharged by irrigation, percolation from streams. Important source of water in the upper reaches of the Snake River and in flanking tributary valleys.	Total dissolved solids *rarely* more than 1,000 generally less than 500 mg/l. Water generally moderately hard to very hard.
QTv: Basaltic volcanic rocks of the Snake River and Idaho Groups, chiefly extruded as cones and domes in the Snake River Plain and bordering areas, Middle Pliocene to Holocene in age.	Olivine basalt, light to dark gray, dense to vesicular, sometimes open textured; irregular to columnar jointing. Includes beds of basaltic cinders, rubbly basalt and scoria, *and stratified interbeds of* clastic and pyroclastic rocks. Flows range from about 10 to 50 feet thick, probably average 20 to 25 feet thick.	Unit constitutes the Snake Plain aquifer east of Bliss, one of the most productive in the United States. Center of individual lava flow generally has low permeability. Water moves through porous rubbly interflow zones. Where saturated *thickness* is 100 to 200 feet, wells commonly yield 1,000 to 3,000 gpm with a few feet of drawdown. Specific capacities of 500-1,000 gpm per foot are common.	Total dissolved solids generally less than 700 mg/l, hardness 100 to 250 mg/l.
QTs: Sedimentary deposits of lacustrine and fluvial origin; *includes* sediments of Snake River and Idaho Groups west of Twin Falls; Salt Lake Fm. east of Twin Falls; Pliocene and Miocene sediments in Wyoming (Tpm on State of Wyoming map). Miocene to Pleistocene in age.	Stratified, thin- to thick-bedded slightly consolidated clay, silt, sand, gravel, carbonaceous shale, volcanic ash, tuffaceous silt and sand, water-laid *fragmented* material and distomite. Includes minor amounts of interbedded basalt, rhyolite, and tuff.	Well-sorted sand and gravel strata are permeable and *yield* moderate *quantities* of water. Wells yield 50 to a few hundred gallons per minute where 50 to 100 feet of the coarser material is saturated.	Dissolved solids less than 700 mg/l; water generally moderately hard to hard, sometimes very hard.
Tsv: Silicic volcanic rocks, chiefly welded tuff and flows of latitic and rhyolitic composition (Tsv on State of Idaho map). Includes Idavada volcanic rocks of Malde, and others. Miocene to Pliocene in age.	Silicic latite; chiefly thick layers of devitrified welded tuff, but includes some bedded vitric tuff and lava flows; rhyolitic tuff and flows. *Predominantly* porphyritic. Contains interbeds of pyroclastic and clastic rocks including shale, sandstone, and conglomerate.	Porosity generally low, permeability highly variable. Fractures and interflow zones yield large quantities of water to wells (100 to 2,000 gpm) at some places; but massive, unbroken rock yields little water. Sand, tuff, and ash beds yield moderate quantities of water. Small to moderate yields for domestic and stock use generally available. Water commonly under artesian pressure. Numerous hot springs.	Dissolved solids generally less than 1,000 mg/l. Water soft to moderately hard. Water from some wells is warm.
Tos: Consolidated sedimentary strata chiefly Paleocene, Eocene, and Oligocene in age. Occur only in Wyoming part of the subregion.	Variegated claystone, shale, sandstone, lenticular conglomerate; sandstone, shale, coal sequences; volcanic *pebble conglomerate;* tuffaceous claystone; tuff, tuffaceous marl.	Porosity low, permeability highly variable but generally low. Few data available but *probably will yield only* small supplies at most places. Occasional wells in sandstone or limestone may yield moderate to large supplies.	Dissolved solids generally less than 500 mg/l; water hard to very hard. Highly mineralized warm to hot water in places.
Tcv: Challis Volcanics; volcanic rocks of variable composition cropping out north of Snake River Plain in Idaho. Eocene(?) to Miocene(?) in age.	Extrusive rocks, ranging *from rhyolite* to basalt; includes welded tuff, pyroclastic, tuffaceous, and *other sedimentary rocks;* includes some intrusive rocks of early Tertiary age.	Little information available, but apparently has generally low porosity and permeability. Yields small amounts of water where coarse grained or jointed. Probably will yield supplies adequate for domestic and stock use at most places.	No data available. Water probably low in dissolved solids, hard.
pT: Pre-Tertiary rocks including intrusive igneous rocks of *the Idaho batholith and* Paleozoic and Mesozoic sedimentary formations.	Indurated limestone, sandstone, shale both south and north of the Snake River Plain. Granite and other intrusive rocks form central Idaho mountain *mass.*	Porosity low. Joints, faults, and other fractures serve as conduits for ground water. Weathered zone on granite, with talus and colluvium, forms shallow reservoir that maintains base flow of streams. Large yields obtained from limestone at some places.	Water from granitic and metamorphic rocks generally low in dissolved solids. Numerous mineralized hot springs discharge from unit.



LOCATION MAP

Base Rev. Oct 1969



COLUMBIA - NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

AQUIFER UNITS

UPPER SNAKE SUBREGION 4

1968

FIGURE 303


LOCATION MAP
Base Rev. Oct 1969
IDAHO
MONTANA
IDAHO
NEVADA
IDAHO
UTAH
NEVADA
UTAH
CUSTER
LEMHI
CLARK
FREMONT
JEFFERSON
MADISON
BUTTE
BLAINE
CAMAS
ELMORE
GOODING
LINCOLN
JEROME
MINIDOKA
TWIN FALLS
CASSIA
POWER
BINGHAM
BONNEVILLE
BANNOCK
CARIBOU
ONEIDA
BOX ELDER
ELKO
IDAHO FALLS
POCATELLO
RUPERT
TWIN FALLS
MILNER DAM
LAKE WALCOTT
AMERICAN FALLS RES.
ISLAND PARK RES.
MACKAY RES.
MUD LAKE
LITTLE WOOD RIVER RES.
FISH CREEK RES.
MAGIC RES.
TWIN LAKES RES.
CEDAR CREEK RES.
SALMON CREEK RES.
LOWER GOOSE CREEK RES.
SCALE IN MILES

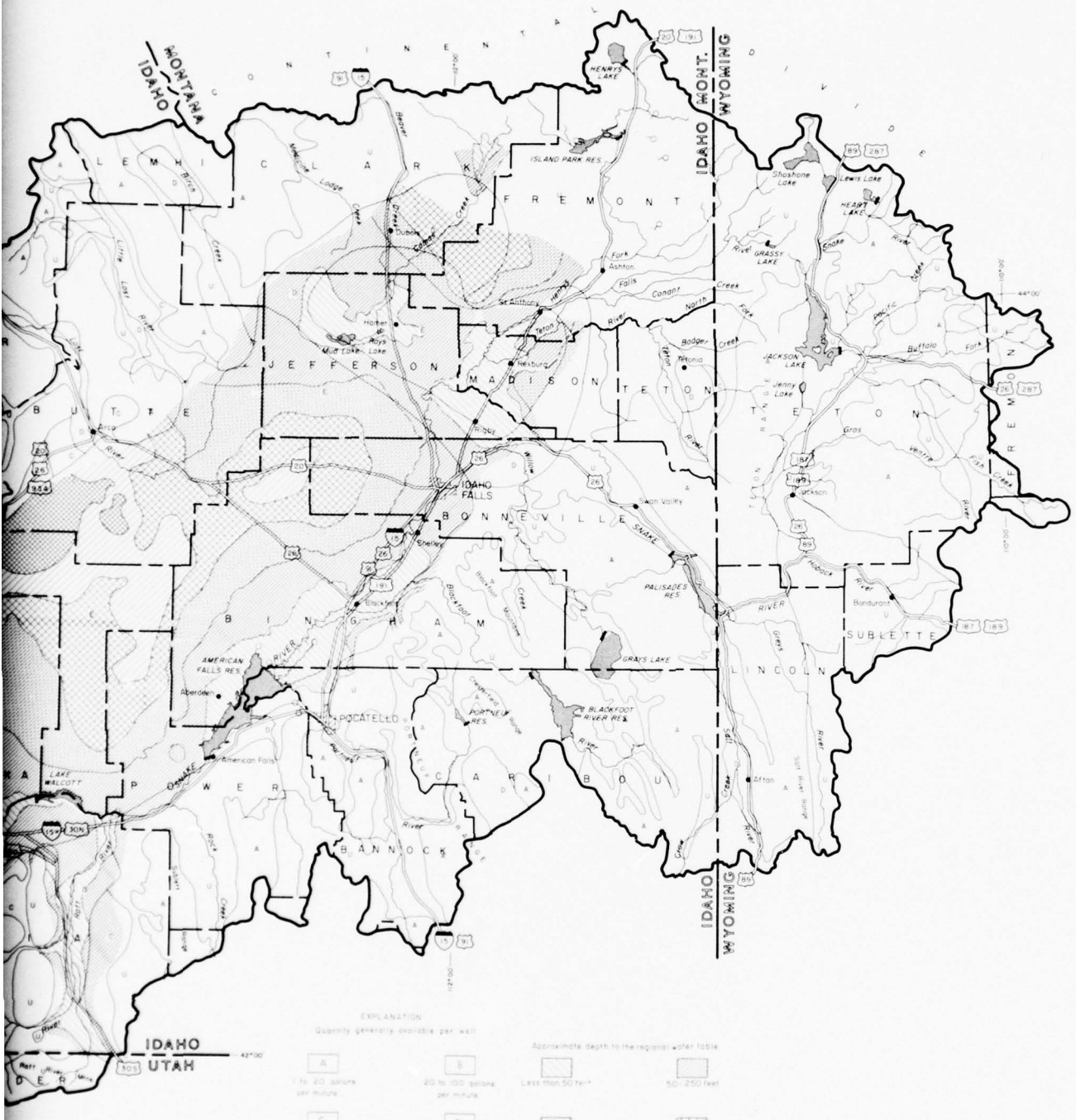

IDAHO
MONTANA
IDAHO
MONT.
WYOMING
IDAHO
WYOMING
IDAHO
UTAH
LEMHI
CLARK
FREMONT
JEFFERSON
MADISON
TETON
BUTTE
BONNEVILLE
BINGHAM
POWER
BANNOCK
CARIBOU
LINCOLN
SUBLETTE
TETON
REMONT
HENRYS LAKE
ISLAND PARK RES.
Shoshone Lake
Lewis Lake
HEART LAKE
GRASSY LAKE
JACKSON LAKE
Jenny Lake
Dubois
St Anthony
Hatter
Mud Lake
Hibburn
Terreton
Jackson
Gros
Ventre
IDAHO FALLS
Ucon Valley
Ucon
Blackfoot
PALISADES RES.
Bondurant
GRAYS LAKE
AMERICAN FALLS RES.
Aberdeen
POCATELLO
PORTNEUF RES.
BLACKFOOT RIVER RES.
American Falls
LAKE WALCOTT
Arbon
Arbon Valley
Snake
Teton
Fork
Falls
Canal
Creek
River
Buffalo
Pacific
Hoback
Portneuf
Ridge
Marsh
Valley
Rock
Sublett
Birch
Lodge
Little Lost
Medicine
Beaver
Badger
Willow
Mountain
Range
Hills
Mtns
Lake
Reservoir
Res.
Falls
Canal
Fork
Creek
River
Valley
Ridge
Mtns
Hills
Range
Marsh
Rock
Sublett
Birch
Lodge
Little Lost
Medicine
Beaver
Badger
Willow
Mountain
Hoback
Portneuf
Pacific
Buffalo
Gros
Ventre
Jenny
Jackson
Ucon
Arbon
Blackfoot
Aberdeen
Bondurant
Dubois
Hibburn
Terreton
Hatter
Mud
Shoshone
Lewis
Heart
Grassy
Henrys
Island Park
Grays
American Falls
Lake Walcott
Palisades
Portneuf
Blackfoot River
Ucon Valley
St Anthony
Jackson
Pocatello
Idaho Falls

Table 167. Storage, Recharge, and Discharge of Ground Water in Aquifer Units in Subregion 4

Aquifer Unit	Sq. Mi.	Acres (1000's)	Specific Yield (percent)	Depth Used (ft)	Water (1000's ac-ft)	Annual Recharge and Discharge Inches Over Area	Annual Recharge and Discharge 1,000's (ac-ft)
Qal	6,400	4,100	20	50	40,000	-	5,000
QTv	10,750	6,900	5	100	34,000	-	10,000
QTs	2,410	1,540	10	100	15,000	3	400
Tsv	4,030	2,580	2	100	5,000	3	650
Tos	865	550	2	50	550	6	275
Tcv	1,150	740	1	50	370	3	180
pT	9,000	5,750	1	50	2,700	3	1,440
QTvs 1/	870	550	5 1/	100	2,500	3	140
TOTAL (rounded)	35,000	22,700			100,000		18,000

1/ The geology of Nevada has been only partly mapped. The area shown on the aquifer-unit map, Figure 303, as Quaternary and Tertiary volcanic rocks and sediments (QTs) includes the younger basalt (QTv), younger Tertiary sedimentary deposits (QTs), and silicic volcanic rocks (Tsv). A specific yield of 5 percent was used for the area.

because the water table is in this weathered zone, the upper 50 feet of saturated material has a higher specific yield than the unweathered rock. A specific yield of 1 percent was assigned to those units.

A storage depth of 100 feet was used for the younger basalt (QTv), the younger sedimentary deposits (QTs), and the silicic volcanic rocks (Tsv); 50 feet was used for all other units. According to table 167, about 100 million acre-feet of water is stored within the specified depth interval in the aquifer units. Nearly 75 percent of this is in the two major aquifers (Qal, QTv) and an additional 20 percent is stored in the two less important aquifers (QTs, Tsv).

Natural Recharge and Discharge

The Challis volcanics (Tcv), the older consolidated sedimentary rocks (Tos), and the pre-Tertiary rocks (pT) are largely confined to mountainous areas which are underlain chiefly by those rocks. Recharge to these units is mostly from direct rainfall and snowmelt during spring and early summer; but there is also some recharge from rainfall in late summer and fall, especially at lower altitudes. The aquifers discharge primarily into the many relatively short streams draining the mountains and secondarily

into the aquifer units underlying the valleys and basins. Much of the ground-water effluent entering the streams in the mountains eventually also recharges aquifers in the valleys.

The younger sedimentary deposits (QTs) and the silicic volcanic rocks (Tsv) crop out extensively in benches and broad uplands, where they are recharged by direct rainfall, by snowmelt, and to some extent by influent seepage from streams draining the bordering mountain ranges. They discharge by underflow into adjoining lowland aquifers and by seepage into streams which, in turn, are influent to aquifers in the basins.

The basins and plains are underlain chiefly by alluvial deposits (Qal) and younger basaltic volcanic rocks (QTv). Precipitation is generally less than 10 inches and recharge from precipitation is minor. Most of the recharge is by infiltration of surface runoff generated on peripheral mountains and highlands. Prior to extensive irrigation, recharge was mainly from influent seepage from short creeks terminating in the alluvium at the base of mountains and from the Snake River, Teton River, and Henrys Fork. After settlement of the area, seepage from irrigation became a very important source of recharge to the Snake River Plain and peripheral basins. Leakage from hundreds of canals and farm laterals and seepage from irrigated farms have greatly augmented flow in the underlying aquifers.

Aquifers underlying all peripheral basins, except those basins downstream from Milner Dam on the south side of the Snake River, discharge into the Snake Plain aquifer; and much of the surface discharge from the same basins also becomes recharge to the aquifer. Discharge from the Snake Plain aquifer is into the Snake River in two reaches: the American Falls Reservoir reach and the Hagerman Valley reach. During the decade 1951-60, the aquifer discharged an average of about 2,500 and 6,500 cfs into the respective reaches. (82-3) All of the water discharging into the American Falls Reservoir reach is rediverted for irrigation and constitutes a portion of the 6,500 cfs discharging in the Hagerman Valley reach.

Table 167 shows average annual discharge of about 18 million acre-feet, about 15 million acre-feet from the two major aquifers alone. Because recharge and discharge are approximately in equilibrium, this represents a rough estimate of annual gross recharge and natural and pumped discharge from the aquifers in the area. Some water cycles in and out of aquifers at least three times as it moves from the upper end of the basin to the lower end. Thus, although 15 million acre-feet may be roughly the gross annual recharge to the two major aquifers, net recharge is considerably less, perhaps on the order of 8 or 10 million acre-feet. Aquifers at the lower end of Subregion 4 discharge into the Snake River above

King Hill. The quantity varies considerably from year to year because of differences in the amount of water diverted for irrigation on the plain which depends, in part, upon annual precipitation in the subregion. The quantity of ground water discharged from the Snake Plain aquifer for the period 1951-55 was estimated to average about 6,500 cfs. (86-180) According to Burnham and others (12-25 and figure 18), estimated discharge during the period 1956-59 averaged nearly 6,700 cfs, but after 1959 the discharge declined, in part, because of increased pumpage. Average discharge for the period 1960-65 was estimated to be about 6,200 cfs. (12-25 and figure 18) The average discharge by 1970 may be on the order of 6,000 cfs. In addition, about 1,000 cfs discharges from aquifers on the south side of the Snake River below Milner Dam. (80-7) Total ground-water discharge from the subregion is about 7,000 cfs or 5 million acre-feet a year. Probably at least another 3 or 4 million acre-feet of ground water is being consumed in the subregion. Much of this, originating from springs and seeps, is diverted from streams or reservoirs for irrigation use.

Hydrographs of representative wells and selected streams are shown in figures 305 and 306.

Annual Ground-Water Withdrawal

Ground-water withdrawal (table 168), based on 1967 data and projected to 1970, is estimated to be about 2.5 million acre-feet a year. About 2.4 million acre-feet a year is withdrawn for irrigation, chiefly from the alluvial deposits (Qal) and the younger basalts (QTv).

Chemical Quality of Water

Water from the alluvial deposits (Qal) and the younger volcanic rocks (QTv) usually is satisfactory for nearly all uses. Dissolved solids generally are less than 500 mg/l and probably average less than 300 mg/l. The water is chiefly of the calcium magnesium bicarbonate type. Silica commonly ranges from 20 to 50 mg/l and probably averages about 30 mg/l. Generally the sodium hazard is low and the salinity hazard is low to medium. Boron concentrations are low. Locally, total dissolved solids and percent sodium may be considerably higher than usual because of minerals added by percolating irrigation water. Water temperatures usually range from 45° to 55°F., but may be a few degrees higher in water from deeper wells in the volcanic rock. There is some indication of a slight but general deterioration in water quality as water is used and reused in passing from the upper to the lower end of the subregion.

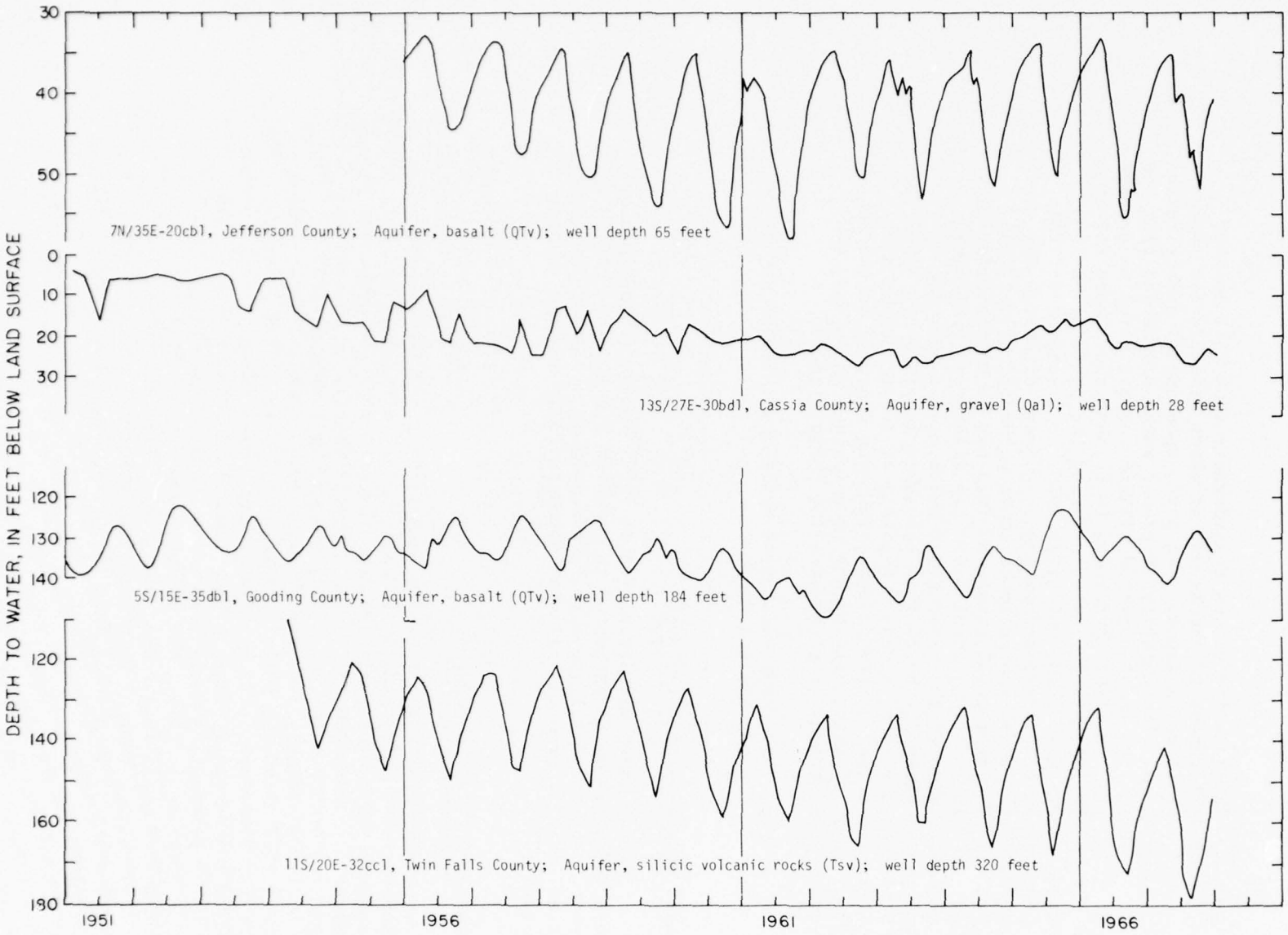


Figure 305 Hydrographs of selected wells in subregion 4

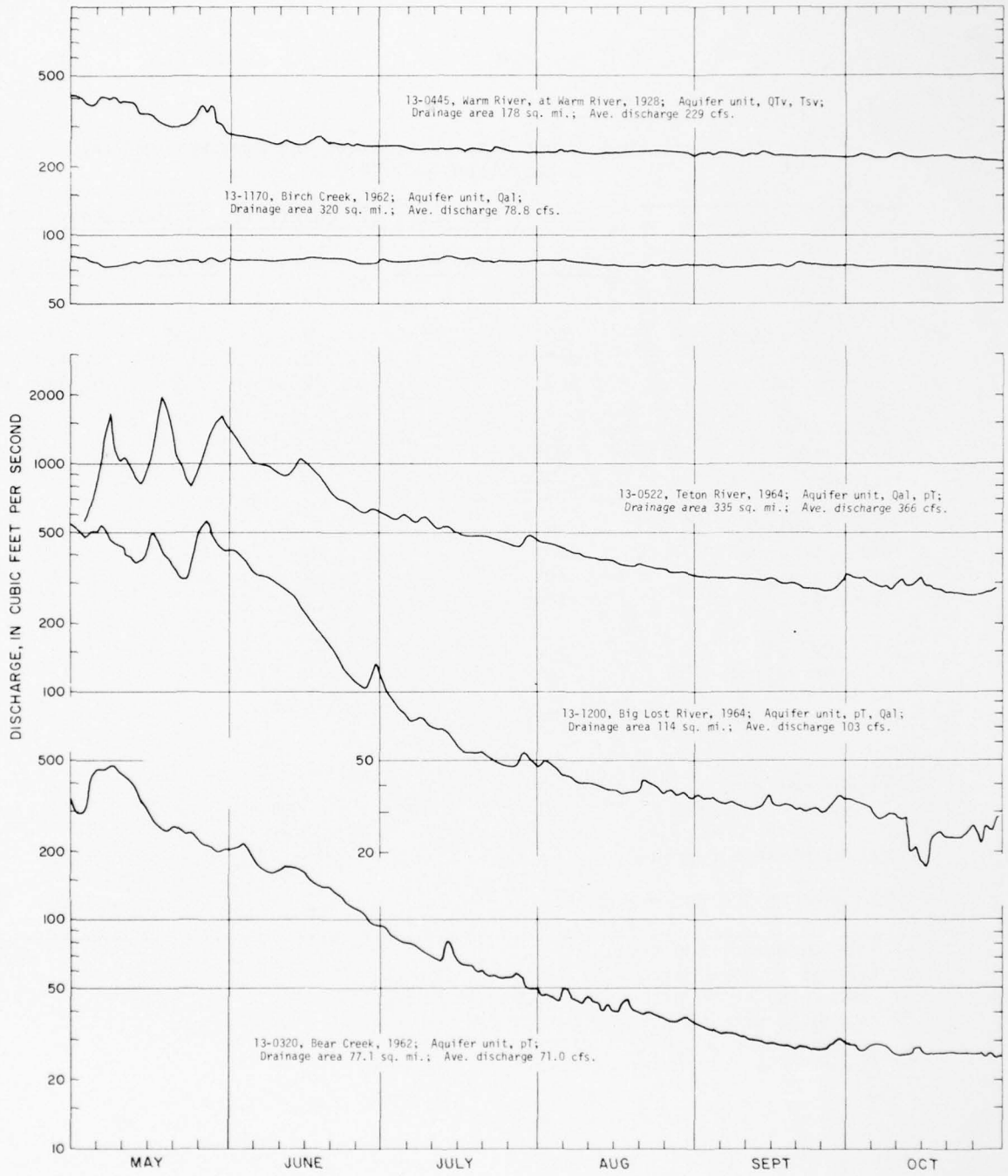


Figure 306 Hydrographs showing low-flow characteristics of selected streams

Table 168 - Estimated Ground-Water Withdrawal and Consumptive Use, Subregion 4, 1970

	Ac-ft per year; all quantities in thousands				
	Idaho	Wyoming	Utah	Nevada	Total
Irrigation					
Acres Irrigated	760	0	0	0.35	760
Withdrawal	2,400	0	0	1	2,400
Consumptive Use	1,300	0	0	.5	1,300
Industrial[1/]					
Withdrawal	62	2.3	-	-	64.3
Consumptive Use[2/]	3.1	.1	-	-	3.2
Public Supplies					
Persons served	180	2	0	0	182
Withdrawal	50	.4	0	0	50
Consumptive use[3/]	10	.1	0	0	10
Rural-Domestic					
Persons served	124	1	-	-	125
Withdrawal[4/]	14	.1	-	-	14
Consumptive use[5/]	7	-	-	-	7
Stock					
Withdrawal and consumptive use[6/]	6	.02	.01	.08	6.1
TOTAL WITHDRAWAL (rounded)					2,530
TOTAL CONSUMPTIVE USE (rounded)					1,300

1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

Table 168 - Estimated Ground-Water Withdrawal and Consumptive Use, Subregion 4, 1970

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	Idaho	Wyoming	Utah	Nevada	Total
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Withdrawal	2,400	0	0	1	2,400
Consumptive Use	1,300	0	0	.5	1,300
Industrial[1/]					
Withdrawal	62	2.3	-	-	64.3
Consumptive Use[2/]	3.1	.1	-	-	3.2
Public Supplies					
Persons served	180	2	0	0	182
Withdrawal	50	.4	0	0	50
Consumptive use[3/]	10	.1	0	0	10
Rural-Domestic					
Persons served	124	1	-	-	125
Withdrawal[4/]	14	.1	-	-	14
Consumptive use[5/]	7	-	-	-	7
Stock					
Withdrawal and consumptive use[6/]	6	.02	.01	.08	6.1
TOTAL WITHDRAWAL (rounded)					2,530
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1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

Water from the younger sedimentary strata (QTs) and the silicic volcanic rocks (Tsv) have somewhat higher concentrations of dissolved solids, but the concentration is generally less than 700 mg/l and rarely exceeds 1,000 mg/l. Average concentration probably is 400 to 500 mg/l. The percent sodium in water from the younger sedimentary strata (QTs) usually is higher than in water from the alluvial deposits (Qal) and the younger volcanic rocks (QTv) but still is commonly less than 50 percent. The sodium adsorption ratio rarely exceeds 4 and generally ranges from less than 1 to 3. Fluoride exceeds 1 mg/l in a few of the samples; boron in excess of 0.3 mg/l is rare. Water from some wells in the silicic volcanic rocks (Tsv) is warm.

Water from the older rock units (Tos, Tcv, and pT) generally has dissolved-solids concentrations of less than 500 mg/l, and is moderately to very hard. Highly mineralized warm to hot water occurs at some places.

Chemical analyses are listed in many of the areal reports cited previously. A discussion of the chemical types of water in the upper Snake River Basin is given by Walker. (180)

Present Use and Future Availability

Total pumped ground-water withdrawals were estimated to be about 2.4 million acre-feet in 1967, with about 2.3 million acre-feet being pumped for irrigation.

In addition, nearly 2 million acre-feet of ground water that discharges into American Falls Reservoir is diverted annually for irrigation and a large part of other surface-water diversions consists of ground-water effluent.

Of the pumped ground water, nearly 500,000 acre-feet is from aquifers in basins peripheral to the Snake River Plain and about 1.9 million acre-feet is from aquifers in the Snake River Plain.

In the basins on the north flank of the Snake River Plain, much of the ground water pumped is for supplemental irrigation. Pumpage varies greatly from year to year, depending on availability of surface water supplies and seasonal precipitation. The quantities given for these basins represent the general level of development for the 1965-67 period, not necessarily the actual pumpage in 1967. Withdrawals from these basins are entirely from the alluvial depsits (Qal). Estimated quantities were: Camas Prairie, 2,000 acre-feet; Big Wood River-Silver Creek, 10,000 acre-feet; Big Lost River, 40,000 acre-feet; and Little Lost River, 40,000 acre-feet. Withdrawal in the Teton Basin was from the alluvial deposits (Qal) and

probably did not exceed 2,000 acre-feet. Withdrawals from basins in the southeast flank of the Snake River Plain were about as follows: Rexburg Bench, 25,000 acre-feet from the younger volcanic rocks (QTv) and the silicic volcanic rocks (Tsv); Michaud Flats, 20,000 acre-feet from the younger sedimentary deposits (QTs) and the silicic volcanic rocks (Tsv); Raft River Basin, 160,000 acre-feet from the alluvial deposits (Qal), the younger sedimentary deposits (QTs), and the silicic volcanic rocks (Tsv); Goose Creek-Rock Creek area, 185,000 acre-feet from the alluvial deposits (Qal), the younger volcanic rocks (QTv), the silicic volcanic rocks (Tsv), and the pre-Tertiary rocks (pT); and Salmon Falls area 8,000 acre-feet from the younger volcanic rocks (QTv) and the silicic volcanic rocks (Tsv).[1/] Withdrawals on the Snake River Plain, 1.9 million acre-feet, are largely from the younger volcanic rocks (QTv); but many wells along the Snake River and southeast of the river between St. Anthony and Pocatello obtain water from the alluvial deposits (Qal).

Pumped withdrawals in Subregion 4 were estimated to be 2.4 million acre-feet in 1967 and 2.5 million acre-feet by 1970; consumptive use is estimated to be about 1.2 and 1.3 million acre-feet, respectively. Net withdrawal of ground water by pumpage in 1967 probably was a little more than consumptive use. No attempt was made to compute the total cumulative net withdrawal of ground water since pumpage became quantitatively significant about 15 years previously. However, the total quality of ground water used consumptively during this 15-year period probably is on the order of 10 million acre-feet. A very brief check of hydrographs and the decline of the water table shown in figure 26 by Burnham (12, figure 26) indicates that withdrawal from storage in the Snake Plain aquifer probably was less than 0.5 million acre-feet, assuming a specific yield of 5 percent. Withdrawal from storage from the alluvial deposits (Qal) in flanking basins, chiefly from Raft River Basin, probably was about 0.5 million acre-feet, making a total withdrawal of about 1 million acre-feet. Thus, it seems apparent that the remaining 9 million acre-feet of ground water used was supplied by depleting the natural discharge from the aquifer or from an increase in recharge. Well hydrographs (12, figure 26) also indicate that there was no depletion of storage of the Snake Plain aquifer between about 1962 and 1966.

As indicated by the map showing general availability of ground water, figure 304, and described in previous sections, it is obvious that large quantities of water can be obtained at many places in the Snake River Basin. Wells yield large to very large amounts of water nearly everywhere in the Snake River Plain; however, utilization is limited by the depth to water. The depth to water

1/ Data in part from Burnham, W. L., and others. (12)

increases northwest and north of the Snake River and exceeds 1,000 feet in places (figure 304).

It is also clear that surface and ground water are very closely related at many places in the subregion. Development of large supplies of ground water at the eastern end of the plain affects, to some degree, return flows to American Falls Reservoir. However, withdrawal from the Snake Plain aquifer downgradient from the American Falls Reservoir has no effect on the surface water supply presently used for irrigation in Subregion 4. Withdrawals in that reach affect discharge from the aquifer in the Hagerman Valley reach--thus the downstream availability of water. Ground-water withdrawals on the south side of the Snake River downstream from Milner Dam also have little or no effect on the available surface water supply for Subregion 4.

In some of the flanking basins of the Snake River Plain large quantities of ground water are available. However, in parts of most of these basins, surface and ground water are closely related; therefore, development of large supplies of ground water may have an adverse effect on the surface water supply. Also, water in these basins is influent to the Snake River Plain aquifer and use of water in the flanking basins affects the availability of ground water in the Snake River Plain. Because the water table has been lowered by pumping, Raft River Basin and Goose Creek-Rock Creek areas have been declared critical by the Idaho State Reclamation Engineer.

Artificial Recharge

No planned artificial recharge is being done in Subregion 4 at present; however, recharge incidental to irrigation is a major factor in the hydrologic regimen. In 1962, a study of the feasibility of artificial recharge of aquifers underlying the Snake River Plain was made by the Bureau of Reclamation and the Geological Survey. (166 and 180) The study concluded that surplus water for recharging was available from Henrys Fork and the Snake River, and that artificial recharge was hydrologically feasible. There are several places where water could be diverted to flow by gravity to recharge sites on the Snake River Plain.

Numerous opportunities also exist for artificial recharge in basins flanking the Snake River Plain. Big and Little Lost River Basins, for example, are underlain by extensive alluvial deposits and the water table is at considerable depths beneath terraces along the flanks of the basins. Surplus winter and spring flows in Big and Little Lost Rivers could be diverted to recharge the alluvium.

The Raft River, Goose Creek, and other basins on the south side of the Snake River also are underlain by aquifers suitable for recharging. There is no surplus water available in these basins and recharge water would need to be imported from the Snake River, the only available source. Because the areas where recharge is needed are at considerably higher altitudes than the feasible diversion points, pumping would be required.

Conjunctive use of surface and ground water may offer the greatest opportunity for optimum utilization of the water supply.

A report prepared by the Bureau of Reclamation and the Corps of Engineers (167 Sec. 7-75 to 83 proposed that both surface and ground water be used in the Raft River and Goose Creek Basins. Surface water would be pumped from the Snake River and diverted to the areas. Pumpage from wells would utilize the ground-water supply which would be augmented by seepage from the irrigation project. The proportion of surface and ground water used would vary from year to year with more ground water being pumped in dry years.

Water Rights

Idaho

Ground water has been developed extensively within the upper Snake River Basin, and rights consist mainly of irrigation use under permits and licenses. There has never been an area- or basinwide adjudication of ground-water rights in Idaho.

Ground-water use within the tributary drainage areas was originally a supplement to surface water supplies but more recently it has been for new land reclamation. In some areas, the use of ground water has or will interfere directly with future surface water adjudication rights because of the interconnection of the two water supplies. Because ground-water development appears to have exceeded safe yield of the basins in several areas south of the Snake River, further well development may be prohibited.

On the Snake River Plain extensive improvement of desert lands under ground-water permits has taken place. No major areas of water-right conflicts have resulted and no serious water shortages are anticipated.

Nevada

Ground-water development within the Nevada portion of Subregion 4 has been small and principally limited to providing supplemental water for irrigation. The development of some additional water by wells in this subregion in Nevada is possible but only subject to existing water rights and agreements. One ground-water development for recreational use is proposed under a permit issued by the State Engineer for the irrigation of a golf course covering some 250 acres. Also several ground-water rights have been issued certificates for commercial purposes to provide facilities for the recreationalists.

Table 168A shows the ground-water rights of record in Nevada. Most uses are of small quantities of water at the present time.

Table 168A - Existing Nevada Ground-Water Rights, Subregion 4, 1969

Status	Railroad	Commercial	Other	Reservoir Storage Rights
	(Cubic Feet Per Second)			(Acre Feet)
Certificates	3			1,080
Permits		2	3	5,670

Wyoming

Ground-water development in the Snake River Basin in Wyoming has been very limited in the past but has accelerated for some uses in the last 5 years.

The use of ground water for irrigation and stock is very limited and this trend is not expected to change in the foreseeable future due to the amount of surface water readily available for these purposes. The main use of ground water is for municipal, domestic, and recreation oriented uses such as fish hatcheries, etc. It is expected that development for these uses will continue on a limited scale as the recreation industry in this part of the basin continues to expand.

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

In Subregion 4, the mountain ranges along the north side and east end of the basin are high rainfall areas and precipitation at the higher elevations generally is 40 to 60 inches. Precipitation on the south and southeast flanks of the basin is less but many mountains receive 25 to 40 inches at higher elevations. Streams receive ground-water effluent throughout the year nearly everywhere in the foothills and mountains. Because most of those areas are underlain by pre-Tertiary rocks of relatively low permeability and limited storage capacity and because of steep hydraulic gradients, base flow decreases greatly during prolonged dry periods. The streams lose part or all of their discharge on reaching the part of the basin underlain by the alluvial-aquifer unit (Qal) and the younger basalt-aquifer unit (QTv). No surface stream draining the north side of the basin between the mouth of Henrys Fork and the Big Wood River, a straight line distance of 160 miles, reaches the Snake River. Flow of these streams is lost to alluvial deposits (Qal) in their respective basins or to alluvial deposits and younger volcanic rocks at the margin of the Snake River Plain.

The Snake River is the trunk drain in the subregion and all outflow from the subregion is through the Snake River. However, through the Snake River Plain, the Snake River alternately gains and loses in several reaches before finally collecting all surface and ground-water discharge near the western end of the subregion. Partial descriptions of gains and losses in the Snake River and the relations of surface water to ground water are given in several reports. (25, 83, 86, 150)

A brief summary is as follows:

1. Snake River loses flow in its alluvial fan reach below Heise to both the regional and perched aquifers.

2. Teton River in its lower reaches and Henrys Fork below St. Anthony are above the regional water table and lose water to it, but receive inflow from perched aquifers.

3. Snake River for several miles downstream from its junction with Henrys Fork near Menan Buttes is at about the same level as the regional water table. The river may alternately gain or lose in this reach depending on river stage and other factors. There are no perched aquifers on the north side of the river but there may be some on the south side.

4. From near Roberts to a point a few miles downstream from Blackfoot, the Snake River is above the regional water table and loses water to it. However, the river may receive inflow from local perched aquifers at some places in this reach.

5. From the point a few miles downstream from Blackfoot to the upper end of Lake Walcott, the Snake River receives inflow from both regional and perched aquifers. Large quantities of ground water are discharged in this reach.

6. From Lake Walcott to about Twin Falls, the river is above the regional water table and loses water to it but receives inflow from perched aquifers in the vicinity of Rupert and Burley.

7. From about Twin Falls to the lower end of the subregion, the river is below the regional and perched aquifers. Large quantities of ground water are discharged to the river in this reach.



LOCATION MAP

SUBREGION 5

SUBREGION 5, CENTRAL SNAKE

HYDROLOGIC FRAMEWORK

Subregion 5 consists of the Snake River drainage from below Oxbow Dam upstream to King Hill, Idaho. This includes the entire lower section of the Snake River Plateau. The area totals 36,825 square miles, with 266 square miles of water and 36,559 square miles of land. It is located in the southwestern portion of Idaho, in the eastern part of Oregon, and in a small part of northern Nevada. Figure 1 shows the subregion boundaries, stream patterns, state and county lines, and other pertinent features.

The subregion lies almost entirely within the Snake River Plateau physiographic province; moreover, it coincides almost exactly with the "Payette section"--the downstream half of the Snake River Plateau. The Payette section is underlain by old lava flows which have been covered by extensive lakebed, alluvial, and windblown deposits. These deposits are naturally covered by sagebrush and grass, and large areas have been made highly productive by irrigation. This subregion also includes small portions of the Northern Rocky Mountains, Blue Mountains, and Basin and Range physiographic provinces.

Inflow from other areas consists of the discharge of the Snake River at King Hill, and possibly minor ground-water flow from other areas. This inflow is primarily ground-water effluent from the Thousand Springs area, augmented at times by sizable uncontrolled floodflows. To this inflow is added the discharge from several major tributaries as the Snake River traverses Subregion 5 to its downstream boundary below Oxbow Dam.

After its entry into Subregion 5, the Snake River remains entrenched in a fairly deep canyon (interspersed occasionally with wider valleys) for over 100 miles as it travels westward from King Hill. In this upper area, only a small amount of easily accessible land along the river had been developed until recently when high-lift pumps have delivered irrigation water to some lands on the plateaus south of the river. After receiving the contribution of the Bruneau River, the Snake River turns gradually northward and emerges from the canyon near Marsing, Idaho. Near Adrian, Oregon, about 30 miles northwest from the canyon mouth, the Snake River

becomes the Idaho-Oregon border, and, as such, winds its way for about 100 miles northward through highly developed farmland. In this reach the Boise, Payette, and Weiser Rivers join the Snake from the east; and the Owyhee and Malheur Rivers enter from the west and southwest. In the vicinity of Huntington, Oregon, the river enters the noted deep Hells Canyon which the river has carved into Columbia River basalts and underlying rock. The Burnt and Powder Rivers, entering from the west in the upper part of this canyon reach, are the last major tributaries to the Snake in Subregion 5.

Runoff from within the subregion is generated principally from snowmelt in the high mountains during the spring and early summer months. The tributary streams east of the Snake River provide the major runoff volumes within the subregion due to the larger amount of mountainous terrain and greater snow accumulation in their drainage basins.

Water is used primarily for irrigation, though considerable amounts are employed for hydroelectric power generation and lesser quantities for municipal and industrial purposes and recreation. Irrigated agriculture began almost a century ago in the subregion, and development has continued since that time.

CLIMATE

In general, the climate of the Central Snake Subregion is characterized by dry, hot summers and by cold winters during which most of the annual precipitation occurs. A wide range in elevations (from 2,000 to 10,000 feet), however, contributes to considerable variation in the climate at individual locations.

Detailed discussions of precipitation, temperature, wind, evaporation, humidity, and sunshine are contained in the following sections.

Precipitation

Precipitation ranges from 8 inches or less per year along the Snake River in southwestern Idaho to more than 60 inches on the Deadwood River Divide in Valley County, Idaho, and up to 80 inches on the high peaks of the Wallowa Mountains in eastern Oregon. All portions of the subregion show a pronounced reduction in average monthly precipitation during July and August. In these 2 months, most of the lower valleys receive less than 1/4 inch of precipitation per month and only the higher level stations receive more than 1/2 inch. In winter and spring, monthly totals average

between 1 and 1-1/2 inches at most lower elevation stations and from 2 to more than 4 inches at higher levels. Table 169 lists the average monthly and annual precipitation for several stations throughout the area.

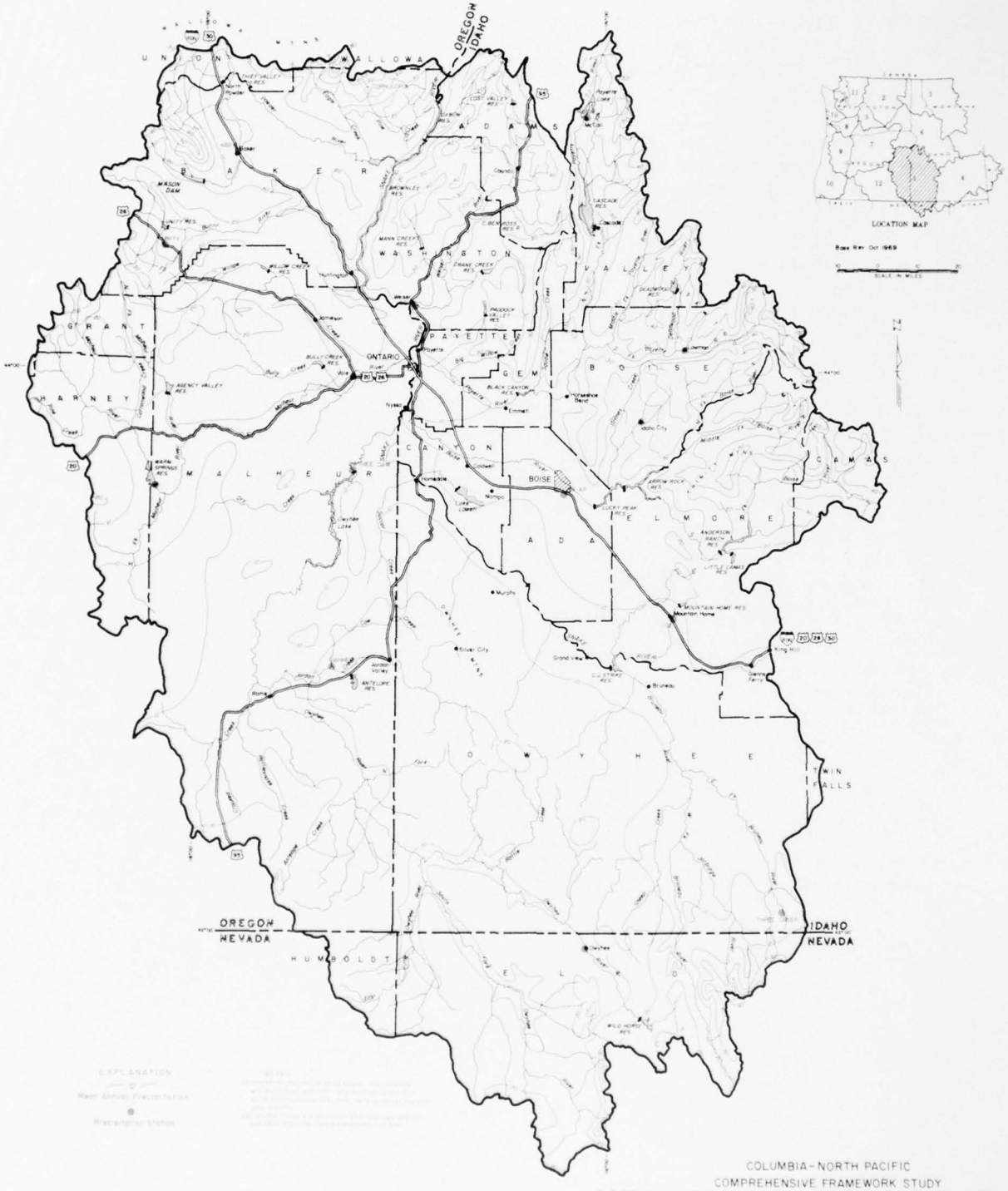
Figure 307 is an isohyetal map of mean annual precipitation prepared by the Weather Bureau River Forecast Center, Portland, Oregon, using climatological data (1930-57) and information derived from correlations with physiographic factors.

Snowfall amounts vary widely within Subregion 5. Some areas in the lower Boise, Payette, and Malheur Valleys receive an average of less than 20 inches per year and often have only intermittent snow cover during the winter. Valley stations at high elevations, on the other hand, average from 100 to nearly 200 inches. More than 24 inches of accumulated snow is almost a certainty each winter at elevated stations such as the town of McCall and Deadwood Dam, high in the Payette River drainage; but an accumulation of this magnitude has never been recorded in the lower Boise, Payette, and Malheur Valleys. In fact, a depth of 6 inches is probable in only about 1 year in 10 at these lower elevations. Snow course observations have been made for a period of over 25 years in the headwaters

Table 169. Average Monthly and Annual Precipitation (Inches), Central Snake Subregion, 1931-60

Station	Elev.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
IDAHO														
Boise WB AP	2841	1.32	1.33	1.32	1.16	1.29	.89	.21	.16	.39	.84	1.20	1.32	11.43
Idaho City	3965	3.41	3.20	2.57	1.68	1.86	1.38	.34	.29	.57	1.62	2.64	3.63	23.19
Lowman 1/	3890	3.38	2.85	2.30	1.72	1.87	1.39	.49	.50	1.01	1.78	3.16	3.59	24.04
McCall	5025	3.62	3.15	2.75	1.87	2.35	2.07	.55	.61	1.19	2.28	2.78	3.53	26.75
Mountain Home 1 SE	3180	1.04	.87	1.10	.84	1.02	.73	.24	.15	.30	.65	.93	.91	8.78
Three Creek 1/	5420	1.11	.89	1.22	1.38	2.19	1.53	.39	.44	.71	1.13	1.01	1.03	13.03
Weiser 2 SE	2120	1.70	1.45	1.11	.90	.99	.82	.11	.22	.39	.86	1.28	1.48	11.31
NEVADA														
Owyhee	5396	1.42	1.17	1.30	1.30	1.79	1.19	.35	.26	.47	1.05	1.07	1.35	12.72
OREGON														
Baker KBKR	3444	.98	.88	1.05	.87	1.44	1.41	.48	.38	.60	.82	1.00	1.06	10.97
Cornucopia 1/	4700	7.29	5.55	4.55	3.12	2.83	2.19	.65	.89	1.61	2.96	5.93	6.86	44.43
Danner	4397	1.21	1.07	1.03	.99	1.36	1.06	.29	.15	.61	.90	1.05	1.32	11.04
Owyhee Dam 1/	2400	.92	.90	.81	.69	1.21	.84	.19	.23	.49	.66	.79	.91	8.64
Unity 1/	4031	1.06	.95	.78	.62	1.38	1.24	.55	.42	.69	.78	.97	1.25	10.69
Vale	2240	1.09	.98	.81	.68	1.03	.80	.17	.24	.46	.77	.85	1.00	8.88
Warm Springs Res.	3336	1.06	.89	.65	.57	.88	1.04	.31	.21	.43	.66	.68	.95	8.33

1/ Period is shorter or longer than the 30-year normal.



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CENTRAL SNAKE SUBREGION 5

1968

FIGURE 307

of the Boise and Payette Rivers at elevations of 7,000 to 7,500 feet. These observations show an average snow depth of 100 inches or greater, with water content of 38 or 39 percent on April 1.

Temperature

Temperatures vary considerably from summer to winter, and from low to high elevations. Nearly all lower elevation stations have recorded a temperature in excess of 110°F. during their period of record as well as a minimum of -20°F. or lower, with many as low as -30°F. At higher elevations, around 5,000 feet, extremes of about 100°F. and -40° to -50°F. have been recorded. Mean annual temperatures are about 38° to 40°F. at higher elevations and 50° to 52°F. in the valleys along the Snake River. Average and extreme temperatures for several stations are shown on table 170.

The average number of days per year with maximum temperatures of 90°F. or higher ranges from five or less at high elevation stations to 50 or 60 in the principal agricultural areas and 70 or more at a few points along the Snake River. Minimum temperatures of 32°F. or lower occur on an average of 140 to 150 days through the broad, agricultural valleys below 3,000 feet and on more than 200 days in the high valleys. The average number of days with a minimum temperature of 0°F. or lower ranges from two or three in the lower Boise, Payette, and Malheur Valleys to 20 or 30 at valley stations above 5,000 feet.

A large daily temperature range occurs during the summer, which reflects the dry air and the general absence of cloudiness. In July, the difference between the average daily maximum temperature and the average daily minimum is from 30 to 40 degrees. In the winter the daily range is considerably smaller, ranging from 15 to about 25 degrees.

The growing season, based on the average dates of last 32°F. minimum temperature in spring and first 32°F. in fall, ranges from 140 to 150 days in the principal low elevation cropland areas of the region to less than 60 in the higher valleys. In general, the growing season for the 28°F. temperature level is 25 to 40 days longer than at 32°F.

Table 170. Average and Extreme Temperatures (°F) Central Snake Subregion

Station	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
IDAHO														
Boise WB AP	Av. Max.	36.0	43.2	51.3	62.0	70.4	77.8	90.3	87.5	77.6	65.1	48.2	39.4	62.4
21-yr.	Av. Min.	20.7	26.5	30.5	37.1	44.2	50.5	58.6	56.3	48.5	39.8	29.8	24.9	39.0
	Mean	29.1	34.5	41.7	50.4	58.2	65.8	75.2	72.1	62.7	51.6	38.6	32.2	51.0
	Highest	63	67	76	92	95	109	111	105	102	88	73	62	111
	Lowest	-17	-10	10	20	27	34	41	38	27	20	-3	-1	-17
Idaho City	Av. Max.	35.6	40.8	48.7	61.1	70.6	77.7	89.9	88.3	79.7	66.6	47.8	38.4	62.1
29-yr.	Av. Min.	10.1	13.8	18.6	27.3	33.9	39.1	43.9	41.2	34.6	28.7	21.1	15.5	27.3
	Mean	22.9	27.3	34.2	44.2	52.2	58.4	66.9	64.8	57.1	47.5	34.5	27.0	44.8
	Highest	56	64	75	88	95	106	109	105	100	91	75	64	109
	Lowest	-38	-35	-20	-8	17	24	26	24	11	9	-17	-25	-38
Mountain Home 1SE	Av. Max.	37.4	43.7	53.7	64.3	73.0	81.1	92.3	89.9	78.1	67.4	50.7	39.8	64.3
52-yr.	Av. Min.	18.2	23.3	27.0	33.4	40.0	46.5	53.6	50.3	41.7	33.9	25.8	20.5	34.5
	Mean	28.3	33.2	40.4	49.6	57.4	64.4	73.7	71.1	62.2	51.9	38.7	31.9	50.2
	Highest	66	72	77	94	102	106	110	106	107	93	76	67	110
	Lowest	-29	-34	5	1	15	30	29	26	9	7	-10	-36	-36
*Three Creek	Av. Max.	39.0	42.4	46.7	58.6	65.7	73.6	87.4	85.8	76.2	63.9	50.2	42.3	61.0
14-yr.	Av. Min.	11.2	16.1	19.8	26.4	32.3	36.5	42.1	38.8	32.2	26.6	19.8	14.5	26.4
	Mean	25.0	29.3	33.3	42.6	49.0	55.1	64.7	62.3	54.1	45.1	34.9	28.5	43.7
	Highest	63	64	70	83	90	98	103	103	99	88	72	66	103
	Lowest	-33	-30	-14	8	12	18	22	18	8	1	-20	-23	-33
Weiser 2SE	Av. Max.	35.2	43.6	55.7	67.1	76.4	84.6	95.6	93.2	82.0	68.4	50.3	38.6	65.9
48-yr.	Av. Min.	17.7	23.8	30.3	36.9	43.6	50.2	56.4	53.5	44.1	35.3	27.0	21.4	36.7
	Mean	27.5	33.3	42.8	52.1	60.1	66.8	75.4	72.5	63.1	52.0	38.5	31.6	51.3
	Highest	65	67	79	93	104	110	115	110	107	97	73	64	115
	Lowest	-27	-20	0	16	23	28	36	32	18	11	-2	-28	-28
OREGON														
Baker KBKR	Av. Max.	33.1	38.4	46.8	57.0	65.0	72.1	81.9	81.0	71.5	62.1	45.7	37.5	57.7
69-yr.	Av. Min.	17.3	22.0	27.4	33.1	39.2	45.1	50.1	48.6	41.3	35.2	26.9	21.9	34.0
	Mean	25.6	30.3	37.5	45.8	53.1	59.0	67.8	65.7	58.5	48.6	36.2	29.6	46.5
	Highest	55	62	77	85	95	99	104	101	99	86	66	60	104
	Lowest	-23	-25	-12	7	19	27	33	31	16	12	-16	-17	-25
Vale	Av. Max.	36.3	43.0	55.0	66.0	74.2	82.1	92.4	90.1	79.4	66.8	49.8	38.7	64.5
63-yr.	Av. Min.	17.4	22.4	28.8	34.3	41.4	47.8	53.4	50.7	41.2	32.6	25.0	20.4	34.6
	Mean	27.3	33.3	42.3	50.9	58.8	65.4	74.2	70.9	61.3	50.7	37.5	31.5	50.3
	Highest	80	66	82	93	101	111	110	110	101	94	75	72	111
	Lowest	-26	-20	-8	14	20	20	33	30	9	9	-10	-39	-39
Warm Springs Res.	Av. Max.	36.4	42.7	52.8	64.0	72.2	79.8	92.1	89.8	80.9	67.5	50.0	40.3	64.0
28-yr.	Av. Min.	16.3	21.2	27.2	33.2	40.1	46.3	53.3	50.9	43.0	34.1	25.0	21.6	34.4
	Mean	26.3	32.0	40.0	48.6	56.2	63.0	72.7	70.4	62.0	50.8	37.5	31.1	49.2
	Highest	61	69	78	88	98	104	109	105	105	88	72	65	109
	Lowest	-36	-34	1	11	17	30	34	30	20	8	-15	-19	-36
Danner	Av. Max.	37.7	42.6	51.3	62.4	70.8	78.2	90.9	89.4	80.3	67.3	51.1	41.5	63.6
29-yr.	Av. Min.	13.5	18.7	24.2	29.7	36.2	42.0	47.3	43.8	35.5	28.7	21.3	18.2	29.9
	Mean	25.7	30.7	37.7	46.0	53.5	60.1	69.1	66.5	57.9	48.0	36.2	29.8	46.8
	Highest	62	69	78	87	99	106	109	105	104	93	86	67	109
	Lowest	-44	-46	-11	10	15	23	29	25	10	0	-23	-34	-46
NEVADA														
Owyhee 1/	Av. Max.	37.2	40.6	46.7	56.7	65.7	74.5	85.9	83.7	74.4	62.9	50.2	41.5	60.0
22-yr.	Av. Min.	15.1	19.2	23.8	30.6	37.2	42.0	50.4	47.6	39.3	32.5	24.0	18.7	31.7
	Mean	26.1	29.9	35.3	43.6	51.4	58.4	68.2	65.6	56.8	47.7	37.1	30.1	45.9
	Highest	67	73	76	85	95	103	106	108	96	92	82	70	108
	Lowest	-35	-28	-14	-1	14	22	25	24	11	0	-10	-32	-35

1/Note: The mean temperature is for the normal period 1931-60; other data are for the period of record.
*The mean temperature is for the period of record.

Wind

Analysis of hourly wind observations for a period of more than 15 years at the Boise Municipal Airport reveals that on an annual basis the wind is from the east-southeast to south-southeast 38 percent of the time, with an average speed of 10.4 miles per hour. During another 34 percent of the time, the wind is from the west-northwest with an average speed of 9.0 miles per hour. At the Mountain Home Air Force Base the winds are from east to southeast 28 percent of the time, with an average speed of 9.5 miles per hour, and from west to northwest 33 percent of the time with an average speed of 10.8 miles per hour. At both Boise and Mountain Home, the southeasterly winds are predominant in the winter, and the northwesterly winds are predominant in the summer. Speeds of 25 miles per hour or more occur less than 1 percent of the time at Boise and less than 2 percent of the time at Mountain Home.

Evaporation

Pan evaporation is estimated at 50 to 55 inches per year in the lower valleys and 40 to 45 inches at higher elevations. Evaporation from lakes and reservoirs ranges from 30 to 40 inches per year. About 80 percent of the annual evaporation occurs in the months of May through October.

Potential evapotranspiration ranges from less than 20 inches per year in the higher valleys to 25 to 30 inches in the main agricultural areas. Actual evapotranspiration from nonirrigated soils is limited by the amount of precipitation, but averages 6 to 10 inches per year from soils with available water-holding capacity of 2 inches and 10 to 15 inches per year from soils with available water-holding capacity of 6 inches.

Humidity

Relative humidity records are not available for the mountains and high valleys, but data for the Mountain Home Air Force Base and the Boise Municipal Airport are fairly typical of the lower valley areas. In July the average relative humidity is only 30 percent at the Mountain Home station and 37 percent at Boise (reflecting the proximity to irrigated croplands); and in December the averages are 76 and 80 percent, respectively. There is a daily variation in humidity which is the inverse of the daily temperature variation. At the Boise Municipal Airport, for example, during July the early morning relative humidity averages 53 percent, while the late afternoon humidity averages 22 percent. In December, the daily range is small, the 5 a.m. average being 84 percent and the 5 p.m. average 75 percent.

Sunshine

Records of cloudiness are limited; but a summary of 27 years of hourly observations at the Boise Municipal Airport shows an average of 124 clear days, 91 partly cloudy days, and 150 cloudy days per year. The difference between summer and winter is striking: July has an average of 22 days clear, 7 days partly cloudy, and only 2 days cloudy; while December and January have averages of 5 clear, 5 partly cloudy, and 21 cloudy days. In the mountain areas, although records are not available, the average cloudiness is undoubtedly greater. The reverse would also apply in areas farther from the mountains than Boise, where the average cloudiness would be less.

Sunshine records at Boise show an average of 67 percent of possible sunshine during a year. Monthly amounts range from 40 percent (3.6 hours per day) in December to 89 percent (13.4 hours per day) in July.

SURFACE WATER

Streamflows which are generated within the Central Snake Subregion originate principally in the eight major tributary basins which feed the Snake River. These tributaries are the Bruneau, Owyhee, Boise, Malheur, Payette, Weiser, Burnt, and Powder Rivers. Storage reservoirs in all the major drainages, except for the Bruneau River, influence to varying degrees the normal pattern of discharge in the streams.

The sequence of flows discharged from the subregion is largely controlled through the operation of Brownlee Reservoir on the Snake River, which has approximately 1 million acre-feet of active storage capacity. During months when a sizable portion of the inflow to this reservoir is stored, the resulting total flow leaving the subregion, when compared with the upstream inflow at King Hill, appears to indicate a negative contribution from Subregion 5. The reverse is also true during the period when storage is released from Brownlee and an apparently larger than normal contribution from the subregion is indicated. Average annual discharges, however, give a true representation of the surface runoff for the area.

Quantity

Average annual discharge from upstream areas (Subregion 4) into Subregion 5 at King Hill is 8,590 cfs; discharge from Subregion 5 at its downstream edge below Oxbow Dam is 16,338 cfs.

This shows an increase of 7,748 cfs (5.6 million acre-feet per year) within the subregion. Subregion 5, therefore, contributes almost as much to the Snake River flow below Oxbow as do the headwater areas in Subregion 4. However, at 0.21 cfs per square mile, this is the next lowest rate of all subregions.

Present Utilization

Estimates were recently made of the amount of water used for various purposes in Subregion 5 during 1965. (115-8) These data show that, with an average withdrawal for consumptive uses of 8,410 cfs, approximately 97 percent was for irrigation. The small remaining withdrawals were made primarily for self-supplied industrial uses and for rural and public supplies. Actual consumption of water was estimated to average 3,240 cfs over the year.

In addition to the above consumptive uses, there also was a moderate amount of water used for nonconsumptive hydroelectric power generation. Other nonconsumptive uses include: (1) fishing, boating, and other recreation on most streams, lakes, and reservoirs, and (2) the dilution and transport of waste materials, both municipal and industrial.

Stream Management

The major purposes for management of streamflow in the subregion are irrigation, flood control, and power production. In the tributary basins, the emphasis is almost entirely on either irrigation or a combination of irrigation and flood control, with some power production on the Boise and Payette Rivers. Daily flows of the Snake River are modified slightly by power operation at run-of-the-river plants; but the only significant control of the Snake River in the subregion is at Brownlee Reservoir, which is operated for power production and flood control.

Impoundments Table 171 lists the reservoirs in Subregion 5 having capacities greater than 5,000 acre-feet. A few of these impoundments are operated singly to serve a specific area or function. The majority, however, are coordinated in some manner with one or more other reservoirs to effect a combined benefit within an individual drainage basin. Irrigated lands for the most part are located along the tributary streams, and coordinated operation between river basins is not required.

As indicated in table 171, several reservoirs are operated for flood control in addition to other functions. Filling of these reservoirs during the spring runoff period is controlled to provide reduction of the peak flood discharges and, at the same time, to obtain the maximum storage supply for irrigation and other functions. Ownership and management of the reservoirs are scattered among several private, public, and Federal entities. Flood control operations, however, are coordinated by the river control officers of the Corps of Engineers and Bureau of Reclamation.

Diversions Large amounts of water are diverted for irrigation from all the major tributaries in the subregion and, to some extent, from the Snake River as well. Most of these diversions have been made by gravity methods through extensive canal systems, although water used from the Snake River has required pumping to lift it to the elevation of the irrigable lands. Extensive areas of land are irrigated in both Idaho and Oregon, and a small amount is irrigated in Nevada.

Channel Modification Levees and other channel improvements have been constructed in local areas along some streams. The problem areas have not been widespread, however, and the improvements are not extensive. Boise and Payette Rivers have a number of local levees. One recent improvement has been the construction of levees for a short distance along the lower end of Bully Creek and along the Malheur River at Vale, Oregon. In other areas, channel clearing and emergency flood protection works have been performed, but the benefits from this work are not permanent.

Forecasting Forecasts of seasonal runoff are used primarily for the scheduling of flood control operations in storage reservoirs. Since the runoff within the subregion is generated principally from snowmelt, the anticipated seasonal volume in the different river basins can be forecast with reasonable accuracy. The scheduling of storage in the reservoirs (or if necessary the evacuation of space) is then determined according to criteria established for the individual streams. Storage space made available for flood control is also used for other purposes; therefore, a prime consideration is to operate the reservoirs during the peak runoff period in such a manner that the storage space will be full when the flood threats have passed.

Table 171 - Reservoirs With a Capacity Greater Than 5,000 Acre-Feet, Subregion 5

Name	Stream	Total Storage (ac-ft)	Active Storage (ac-ft)	Surface Area (acres)	Purpose[3/]
IDAHO					
Anderson Ranch	S. F. Boise R.	493,200	464,200	4,780	FIP
Arrowrock	Boise R.	286,600	286,600	3,050	I
Black Canyon	Payette R.	44,100	1,100	1,045	IP
Brownlee	Snake R.	1,426,700	980,250	15,100	FP
C. Ben Ross	Little Weiser R.[1/]	7,800	7,600	353	I
C. J. Strike	Snake R.	250,000	84,000	7,500	P
Cascade	N. F. Payette R.	703,200[2/]	653,200[2/]	28,300[2/]	FI
Crane Cr.	Crane Cr.	60,000[2/]	60,000[2/]	3,300[2/]	I
Deadwood	Deadwood R.	164,000	161,900	3,000	CIP
Hubbard	Boise R.[1/]	7,500	7,500	-	I
Lake Fork	Lake F. Payette R.	16,950	16,950	1,500	I
Lake Lowell	Boise R.[1/]	190,100	169,000	9,835	I
Little Camas	Little Camas Cr.	22,500	22,300	1,250	I
Lost Valley	Lost Cr.	10,000	10,000	730	I
Lucky Peak	Boise R.	307,000	279,000	2,810	FIR
Mountain Home	Rattlesnake Cr.	5,600	5,600	-	I
Oxbow	Snake R.	57,500[2/]	5,000[2/]	-	P
Paddock Valley	Little Willow Cr.	32,000[2/]	32,000[2/]	1,500[2/]	I
Payette Lake	N. F. Payette R.	35,000[2/]	27,700[2/]	5,000	I
Pleasant Valley	Blacks Cr.	7,900	7,900	403	I
Spangler	Mann Cr.	13,000	11,000	280	CFIR
Swan Falls	Snake R.	-	6,900[2/]	-	P
NEVADA					
Wild Horse	E. F. Owyhee R.	71,680	71,660	2,930	I
Wilson River	S. F. Owyhee R.	10,470	9,000	827	IRCF
Chimney Creek	S. F. Owyhee R.	9,950	9,000	540	IC
OREGON					
Agency Valley	N. F. Malheur R.	60,000	60,000	1,900	I
Antelope	Jordan Cr.[1/]	55,000	55,000	-	I
Bully Cr.	Bully Cr.	31,600	30,200	980	CFIR
Cow Lake	Cow Cr.	5,000[2/]	-	-	I
Love	Willow Springs Cr.	6,000	-	-	I
Mason	Powder R.	100,000	95,000	2,480	CFIR
Owyhee	Owyhee R.	1,120,000	715,000	13,900	I
Thief Valley	Powder R.	17,570	17,400	750	I
Unity	Burnt R.	25,820	25,220	930	I
Warm Springs	Malheur R.	192,400	191,000	4,600	I
Willow Creek No. 3	Willow Cr.	49,000	20,400	1,240	I

1/ Offstream.
2/ About.
3/ P-power, F-flood control, R-recreation, I-irrigation, C-fish and wildlife conservation.

Constraints Flows in the main stem of the Snake River in Subregion 5 have not yet been fully utilized. Therefore, limiting criteria over the physical operation of the stream have not been developed, except for minimum flow requirements below Brownlee and Oxbow Dams. Quality control standards have been adopted, however, which limit the level of pollution which will be tolerated in the river.

Constraints exercised over tributary streams, on the other hand, are much in evidence. Irrigation shortages are experienced on many of these streams during dry years; these shortages have led to court decrees and priority use of the water. In some streams, only the required minimum flows are available in the stream channel during certain periods.

Water Rights

Each of the three states (Idaho, Nevada, and Oregon) which has lands within Subregion 5 subscribes to the water-right doctrine of prior appropriation for beneficial use. Determination of rights and the regulation of streamflow are therefore quite similar throughout the area.

Idaho On the Snake River main stem in Idaho, there are only a few adjudicated rights. Extensive use is made, however, of water for power and irrigation purposes under permits and licenses.

At present, no known water shortages nor conflicts exist between water-right holders on the main stem, although some have expressed concern over the changing flow regimen caused by power releases and forebay storage for peaking. There presently appears to be unappropriated Snake River water available for use. However, pending applications and proposed projects are expected to bring future conflicts resulting in a need for adjudication of rights and supervision of uses. Construction of storage, groundwater development on the Snake River Plain, and continued expansion of high-lift pumping along the river are expected to reduce the future supplies significantly.

South of the Snake River (in Owyhee County, Idaho), the rights on many tributary streams have been adjudicated, and these streams appear to be fully appropriated except during periods of high flows. Permits may still be issued on some streams for construction of storage reservoirs to impound nonirrigation season flows and excess flood discharges. The Bruneau and the Owyhee Rivers are the two major streams in this area; the Bruneau River has uncommitted runoff which offers some possibilities for new

storage developments, while the Owyhee River is heavily appropriated through storage in the existing Owyhee Reservoir.

On the Boise River, the base flow is now fully appropriated under adjudicated rights; and the winter and spring runoff, for the most part, is stored under permits and licenses. Except for additional storage during the extreme flood periods, the existing water supply of the Boise River drainage offers little opportunity for new development, except perhaps on the lower reaches of the river where return flows add to the stream discharge. The Boise River experiences late season low flows which require releases from the storage reservoirs to meet irrigation requirements. Proposed importation of water from adjoining streams and water exchanges may make water available for further irrigation and for other uses such as water quality flows and municipal supplies.

Although the Payette River is used extensively for irrigation purposes, the rights have not been adjudicated except on a few tributary streams. There are a number of permits and licenses, but many uses appear to be the result of claimed "use rights." Existing storage facilities are not presently fully utilized; however, the Payette River is subject to late season water shortages, and the water users will likely find a need for additional storage to augment their supplies as the basin becomes more fully developed.

The discharge of the river measured near Payette, Idaho, (table 180) is, in general, available for additional use. The amounts shown, however, include return flows from upstream irrigation; these would be available for use only in the lower reach of the river.

All water in Big Payette Lake below the minimum natural level of the lake was appropriated by the Governor of Idaho to preserve it for the use of the general public for recreation and scenic purposes. However, the constitutionality and effect of such an appropriation has not been determined.

The last major Idaho tributary which enters the Snake River in Subregion 5 is the Weiser River. Rights have been adjudicated on this stream and its tributaries; and, in addition, a number of permits, licenses, and use rights are in existence. The primary use is for irrigation, with a small amount used for industry. Several storage reservoirs have been built, and storage presents the major opportunity for additional future development.

Nevada The two main Snake River Tributaries that head in Nevada are the Bruneau River and the Owyhee River. The Jarbidge River rises in Nevada, then joins the Bruneau River in Idaho. Most of these waters, even though they originate in Nevada are used for irrigation in Idaho and Oregon. A principal use of the Owyhee River water is for irrigation on the Duck Valley Indian Reservation

straddling the Idaho-Nevada boundary after storage in the newly reconstructed Wild Horse Reservoir with a capacity of 71,660 acre-feet. Smaller reservoirs include Deep Creek, Wilson Creek, Dry Creek, Spring Creek, and Duck Creek with capacities up to 2,000 acre-feet, and Bull Run Creek Reservoir with a capacity of some 10,000 acre-feet.

The only adjudication proceeding completed within the Owyhee River Basin is for Six Mile Creek, although a petition for adjudication of the Owyhee River was filed with the State Engineer in 1924 and dismissed in 1939. However, the Nevada State Engineer has continued to accept claims of a vested right by filing proofs of appropriation which are submitted in accordance with statutory procedures.

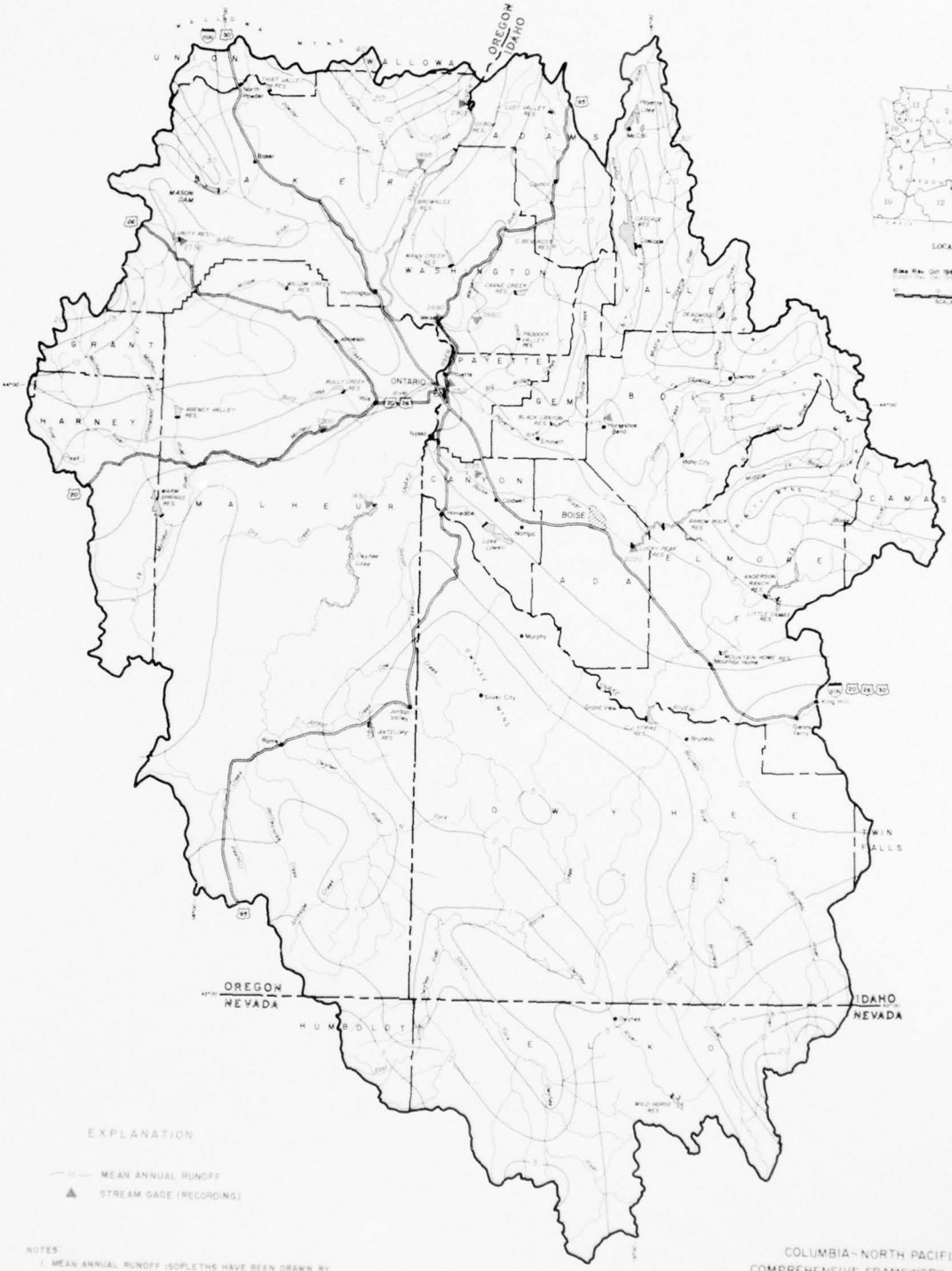
Table 171A - Existing Nevada Surface Water Rights, Subregion 5, 1969
Certificates, Permits, and Applications

Unit	Irrigation	Stockwatering	Other	Reservoir Storage Rights
	(Cubic Feet per Second)			(Acre Feet)
Owyhee		148	10	132,790
Bruneau				7,998
Jarbidge		4	4	127,512

Discharge

The base period used in this study is October 1928 to September 1958 (water years 1929-58). Selection of this period was based on the determination that it adequately reflects the long-term runoff conditions. Unless otherwise shown in the tables, graphs, or narrative, all runoff values have been adjusted to represent streamflow conditions under the present level of development (1970).

Measurement Facilities The 12 stream gage locations at which runoff data are given in this report are indicated on the map of mean annual runoff, figure 308. A summary of some of the pertinent data at each station is given in table 172. On this table the station numbers, datum, and drainage area are those used in Geological Survey reports. Momentary maximum and minimum flows are observed extremes at each station for the period of record available. In most cases these historical peaks were affected by the upstream regulation in effect at that time. Annual flow values have been modified to reflect stream development and use as of 1970.



NOTES:

1. MEAN ANNUAL RUNOFF ISOPLETHS HAVE BEEN DRAWN BY U.S. GEOLOGICAL SURVEY USING OBSERVED STREAMFLOW DATA ADJUSTED TO NATURAL CONDITIONS (1951-1960) AND CORRELATED WITH CLIMATOLOGICAL AND PHYSIOGRAPHIC FACTORS.
2. STATIONS INDICATED DO NOT INCLUDE ALL OF THOSE USED IN PREPARING THE MAP.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES

CENTRAL SNAKE SUBREGION 5

1968

FIGURE 3(

Table 172. Streamflow Summary for Selected Sites, Subregion 5

Stream	Station	Station Number	Gage Datum	Drainage Area (sq.mi.)	Period of Record	Annual Flow 1/ (cfs) Mean	Max.	Min.	Momentary Flow 2/ (cfs) Max.	Min.
Bruneau River	Hot Spring	1685	2598.5	2,630	44-65	342	586	113	6,500	25
Owyhee River	Owyhee Dam	1830	2343.67	11,160	29-65	252	1,604	36	22,900	0
Boise River	Nr. Boise	2020	2827.0	2,680	(95-16 (55-65	2,619	4,207	1,291	35,500	0
Boise River	Notus	2125	2288.55	3,820	20-65	960	2,325	289	20,500	10
Malheur River	Little Valley	2200	2424.03	3,010	49-65	160	523	28	12,300	12
Payette River	Horseshoe Bend	2475	2625.61	2,230	19-65	3,070	4,611	1,834	27,000	350
Payette River	Payette	2510	2138.44	3,240	35-65	2,707	4,521	1,430	30,900	180
Weiser River	Weiser	2660	2220	1,460	52-65	1,004	1,905	424	19,900	14
Snake River	Weiser	2690	2086.64	69,200	11-65	15,074	24,491	9,697	84,500	5,100
Burnt River	Hereford	2730	3756.75	309	29-65	82	148	34	2,220	0
Powder River	Robinette	2895	1937.01	1,660	28-57	512	916	209	5,500	18
Snake River	Oxbow	2902	1668.34	73,150	58-65	16,338	26,037	11,124	76,800	441

1/ Regulated values for base period (1929-1958) 1970 conditions.
2/ Observed values for period of record.

Average Discharge for Subregion 5 Figure 308 is a map of isopleths showing mean annual runoff. Figure 309 presents graphically the average monthly discharge generated within Subregion 5; these same data also are shown in table 173. This runoff consists of the monthly flows passing the Oxbow gage minus the flows passing the King Hill gage during the same months. It should be remembered that storage and use of water on the main stem tributary streams have quite drastically changed the normal pattern and volumes of runoff.

Table 173. Discharge in Subregion 5 (Central Snake), 1929-58
(Mean discharge, in cfs)

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
						Maximum Months						
5,764	7,725	13,936	16,058	21,952	22,203	51,712	37,014	26,706	8,312	4,271	6,850	18,462
						20 Percent						
5,341	6,618	8,533	12,581	12,910	15,120	26,354	19,922	17,366	1,838	2,818	4,610	11,125
						Mean						
4,585	5,547	7,709	10,625	10,314	11,576	15,965	10,877	9,751	135	2,308	4,068	7,748
						80 Percent						
4,165	4,606	6,560	8,858	7,993	9,166	7,008	3,931	2,309	-1,384	1,828	3,472	4,856
						Minimum Months						
2,470	2,884	4,006	7,152	4,431	3,179	-1,608	-1,932	-1,588	-2,187	1,482	2,872	1,754

The data which represent total outflow from the subregion are those shown for the Snake River below Pine Creek at Oxbow on table 185 and figure 321.

Average Discharge for Selected Stations In this section, additional data are given for each of the selected sites listed on table 172. Monthly discharges for each year are shown on tables 174 to 185. These flows reflect regulation and use under the 1970 level of development.

Figures 310 to 321 are flow hydrographs for seven conditions: maximum, mean, and minimum monthly flows; monthly flows for the maximum and minimum years; and monthly flows which are equaled or exceeded 20 percent and 80 percent of the time during the base period.

Frequency curves of annual high and low discharges are shown on figures 322 to 333. These curves present the highest average flow and lowest average flow for periods of 1, 3, 6, and 12 consecutive months. Because streamflow at most stations in this subregion is highly regulated, the frequency curves do not have a normal distribution of high and low discharges.

Duration curves for monthly and annual flows are presented on figures 334 to 345. The curves indicate the percent of time that any given flow is equaled or exceeded at each site. The occurrence of these flows is not necessarily during consecutive months or years, but may have been at any time during the 30-year base period.

Frequency curves of annual peak discharges at four of the 12 selected stream gage sites are shown on figures 346 to 349. Data for the remaining sites are not included because of the high degree of historical regulation on most of these streams. For comparison, both the regulated and unregulated peak flows are shown for the Boise River near Boise.

Dependable yield at the various sites is listed on tables 186 to 197. Values shown are the lowest mean flows that occurred (within the base period) for intervals of 1 to 10 consecutive years. Yield, as a percent of the 30-year mean, varies widely between the different stations. For the lowest single year's discharge, the range is from a high of 68.1 percent to a low of 14.3 percent. During the 10 consecutive years of lowest discharge, the yield varies from 80.6 to 32.5 percent.

Variations in Discharge Long-term variations in discharge for the Snake River at Weiser, Idaho, and in precipitation for Boise are shown on figure 350. Means for the base period (1929-58) and the entire period record are shown on both graphs. The discharge of the Snake River at Weiser shows a base period average (recorded) of 16,960 cfs and a 56-year average of 17,740 cfs; the 30-year base period flow is therefore about 96 percent of the longer (56-year) record. The average annual precipitation at Boise for the base period is 11.51 inches, while for the 99 years of available records, the average is 12.70 inches; the base period precipitation is therefore about 91 percent of a long-term period. In addition, some of the highest and some of the lowest recorded runoff have occurred within the base period. It is thus apparent that for Subregion 5 the base period of 1929 to 1958 adequately represents normal runoff conditions.

Seasonal variations in streamflow can be seen in the hydrographs of figures 310 to 321. A normal cycle of low winter discharge, high spring flows due to snowmelt, and receding flows throughout the summer are characteristic at most sites.

Streamflow Travel Time There is no known information in this reach of the river from which a graph of travel times could be drawn. Some generalized information is in use for routing flood discharges, but the accuracy of these values is not precise.

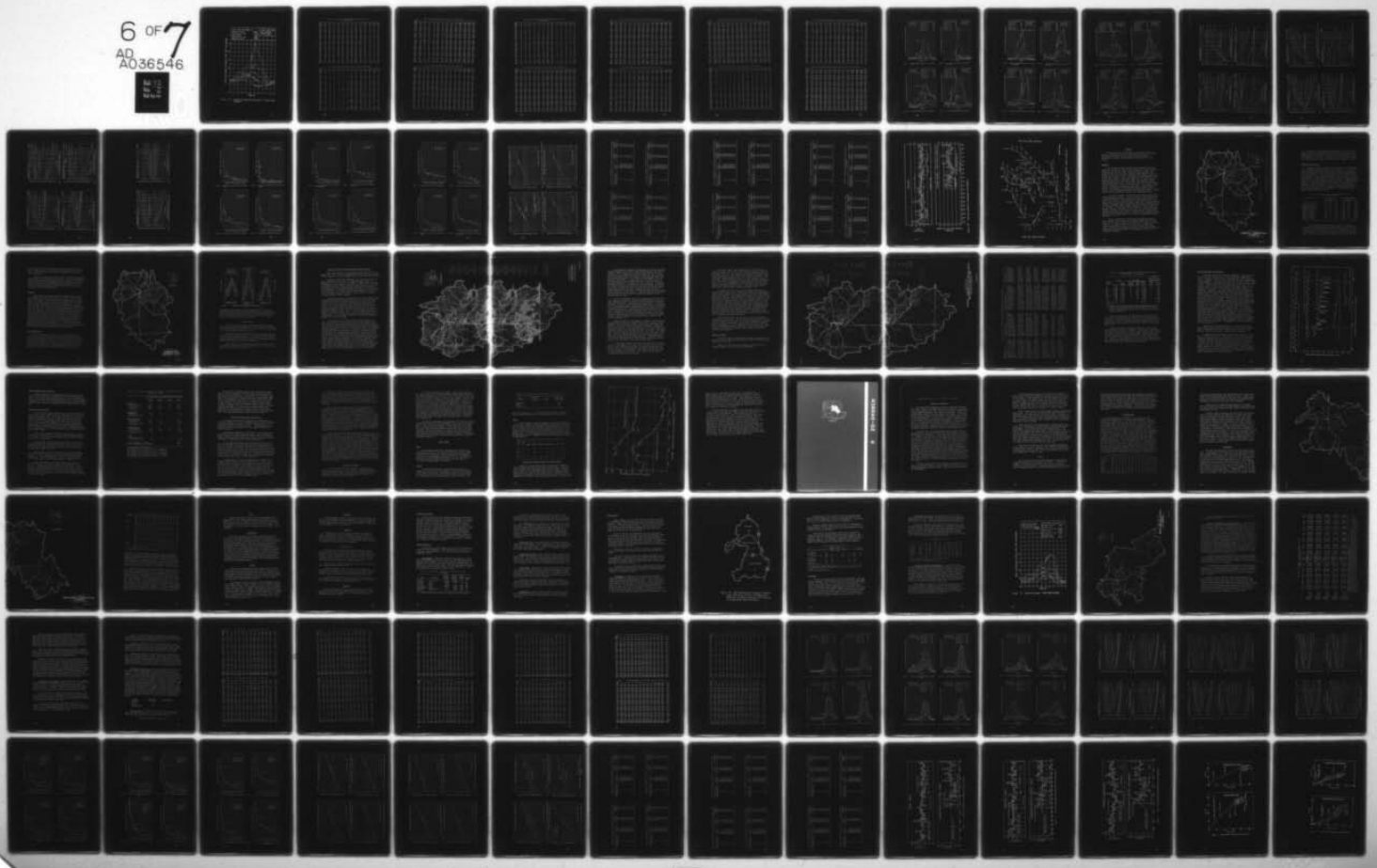
River Profiles Profiles for the central section of the Snake River and selected tributaries are shown in figure 351.

Narrative continued page 456

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COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
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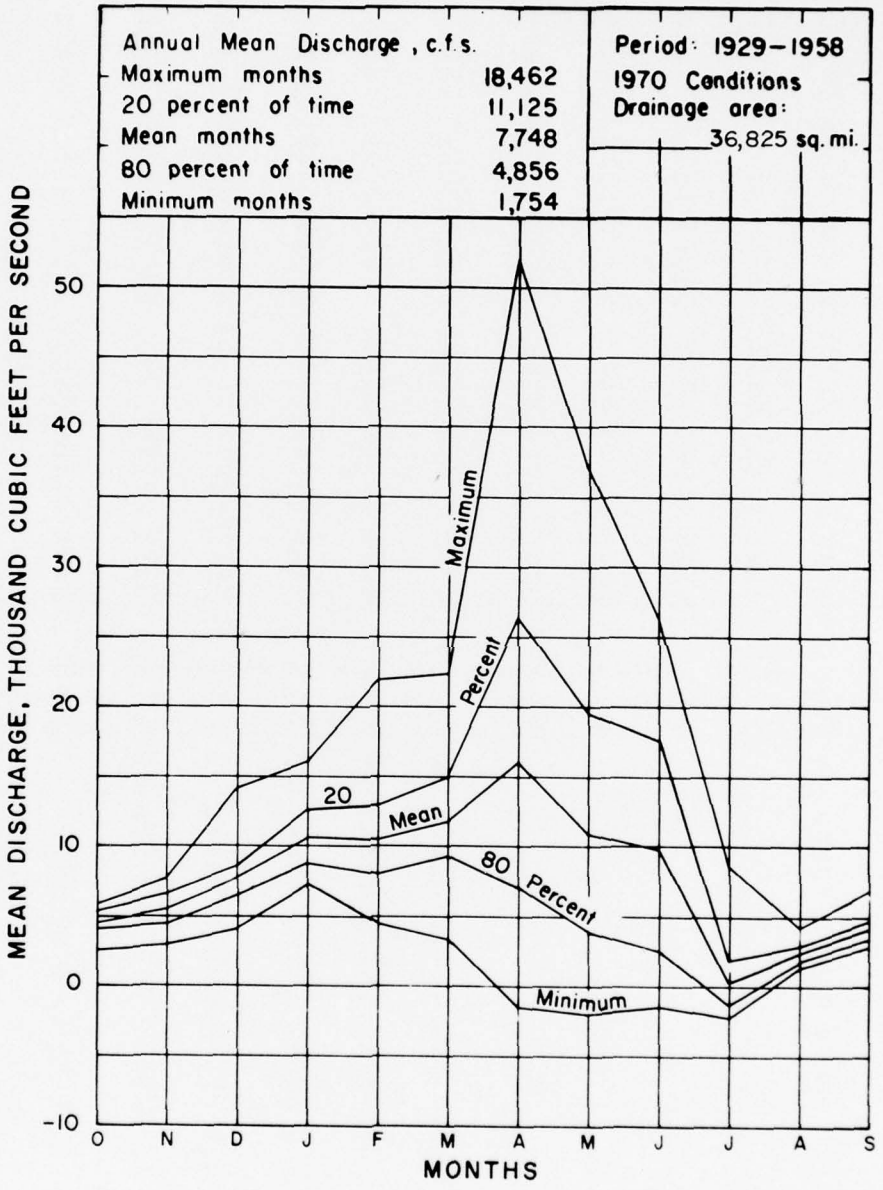


Figure 309 Monthly discharge, flow generated in Central Snake Subregion.

Table 174. Observed and Estimated Mean Discharges in CFS, Bruneau River near Hot Springs, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										163	91	79	0
1929	107	136	112	106	106	236	640	1120	743	192	114	114	311
1930	111	118	122	109	142	174	245	589	271	104	167	126	181
1931	122	106	98	109	117	169	353	260	101	59	60	104	138
1932	107	103	83	101	96	174	753	1506	1486	400	151	126	423
1933	115	124	104	124	110	159	373	806	992	237	99	67	276
1934	107	109	119	128	121	163	178	133	82	75	83	52	113
1935	91	109	112	124	121	193	524	836	1039	259	76	79	297
1936	88	109	112	120	113	159	939	1120	867	140	99	74	328
1937	111	109	115	94	106	190	424	706	418	177	68	42	214
1938	80	109	122	132	124	242	896	1397	944	385	114	109	389
1939	111	128	145	150	117	865	913	582	218	89	60	47	286
1940	73	99	104	128	120	242	508	611	289	59	37	52	194
1941	62	87	98	124	117	202	376	606	548	163	128	94	217
1942	107	133	145	135	139	315	2000	1732	1617	348	122	57	570
1943	76	121	159	350	746	663	1751	1242	1356	421	122	74	586
1944	107	131	124	115	137	185	655	1341	1121	421	124	87	379
1945	102	123	114	130	193	272	837	2018	1607	548	146	111	518
1946	124	153	150	161	171	405	1192	987	676	197	89	81	365
1947	137	148	156	119	209	291	513	872	558	172	80	67	277
1948	80	109	132	148	151	189	588	954	944	229	91	79	307
1949	98	111	107	107	135	239	1386	1823	834	198	96	81	435
1950	115	128	115	210	238	398	1007	1424	1139	372	120	91	447
1951	104	161	273	198	476	420	1269	1389	701	223	115	77	449
1952	94	119	128	133	158	179	1882	2346	1373	395	133	94	586
1953	106	109	128	166	157	242	546	746	1467	416	106	79	355
1954	88	109	112	120	157	239	375	480	276	114	68	61	183
1955	68	81	76	93	99	119	240	600	608	190	76	64	193
1956	70	89	158	314	157	387	818	1299	869	198	85	67	376
1957	86	108	150	91	348	397	666	1997	1397	341	98	82	480
1958	106	126	124	120	243	237	793	1593	761	192	91	71	372
Mean	98	117	127	142	180	278	788	1104	843	244	101	80	342

Table 175. Modified Mean Discharges in CFS, Owyhee River below Owyhee Dam, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										275	257	200	0
1929	50	8	8	8	9	8	437	226	234	275	257	200	144
1930	50	8	8	8	9	8	47	91	94	111	102	82	52
1931	24	8	8	8	9	8	47	91	94	49	42	39	36
1932	20	8	8	8	9	8	109	226	234	275	257	200	114
1933	50	8	8	8	9	8	47	91	94	111	102	82	52
1934	24	8	8	8	9	8	47	91	94	75	44	39	38
1935	20	8	8	8	9	8	109	226	234	275	257	200	114
1936	50	8	8	8	9	8	1655	857	234	275	257	200	297
1937	50	8	8	8	9	8	109	226	234	275	257	200	117
1938	50	8	8	8	9	8	1871	2472	234	275	257	200	452
1939	50	8	8	8	9	8	1403	226	234	275	257	200	223
1940	50	8	8	8	9	8	109	226	234	275	257	200	116
1941	50	8	8	8	9	8	109	226	234	275	257	200	117
1942	50	8	8	8	9	8	109	559	301	275	257	200	151
1943	50	8	8	8	822	3924	4225	226	234	275	257	200	850
1944	50	8	8	8	9	8	109	226	234	275	257	200	116
1945	50	8	8	8	9	8	109	1943	908	275	257	200	318
1946	50	8	8	8	9	1857	4005	226	234	275	257	200	594
1947	50	8	8	8	9	8	109	226	234	275	257	200	117
1948	50	8	8	8	9	8	59	117	121	141	132	104	64
1949	29	8	8	8	9	8	59	117	121	141	132	104	62
1950	29	8	8	8	9	8	59	117	121	141	132	104	62
1951	29	8	8	8	9	8	2358	367	234	275	257	200	312
1952	50	8	8	8	9	8	13230	5050	276	275	257	200	1604
1953	50	8	8	8	9	8	109	226	234	275	257	200	117
1954	50	8	8	8	9	8	47	91	94	111	102	82	52
1955	24	8	8	8	9	8	47	91	94	111	102	82	50
1956	24	8	8	8	9	8	109	226	234	275	257	200	114
1957	50	8	8	8	9	8	906	2746	234	275	257	200	396
1958	50	8	8	8	9	659	4835	1855	234	275	257	200	699
Mean	43	8	8	8	36	222	1219	656	221	225	210	164	252

Table 176. Modified Mean Discharges in CFS, Boise River near Boise, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										4854	4415	3640	0
1929	898	81	80	50	1070	141	1168	4463	4934	4854	4415	3640	2155
1930	881	50	50	29	1050	120	2082	4208	4452	4210	3766	2346	1941
1931	587	660	524	29	1178	255	1109	2076	2486	2685	2405	1507	1291
1932	385	538	442	50	965	724	2197	4463	4934	4854	4415	3640	2302
1933	881	50	50	80	1070	171	1188	4463	4934	4854	4415	3640	2155
1934	898	81	80	80	1070	120	2867	3940	3933	3945	3501	2160	1892
1935	602	733	589	50	1252	125	1155	4463	5008	4475	3998	2501	2083
1936	647	1250	429	50	1070	171	2212	4463	4934	4854	4415	3640	2345
1937	898	81	80	29	1052	120	1155	4463	5008	4475	3998	2501	1994
1938	637	697	885	80	1099	171	4193	7956	6743	4854	4415	3640	2953
1939	898	81	80	80	1070	141	3948	4463	4934	4854	4415	2501	2292
1940	637	1094	29	29	1035	141	2197	4463	4934	4854	4415	2501	2195
1941	647	1114	50	80	1052	120	3217	4463	4218	4475	3998	2501	2164
1942	637	802	782	50	1074	120	2185	4122	4934	4854	4415	2501	2211
1943	637	1094	29	3205	2998	2151	9542	9574	5842	5709	4415	3640	4068
1944	898	81	80	101	1111	980	2309	4463	4144	4854	4415	3640	2260
1945	881	50	50	50	1101	171	1168	4122	4933	4854	4415	3640	2125
1946	881	50	50	80	1101	2621	7588	7644	5509	4854	4415	3640	3209
1947	898	81	80	80	1101	1606	3595	6566	4988	4854	4415	3183	2629
1948	898	81	80	80	1066	171	2995	5537	5793	4854	4415	3640	2468
1949	898	81	80	80	1101	171	4326	6541	4933	4854	4415	3640	2598
1950	898	81	80	80	1101	171	7269	6176	5314	4854	4415	3640	2841
1951	898	81	80	80	1560	3722	9270	7585	6144	4854	4415	3640	3530
1952	898	81	80	3564	2800	3086	8884	8447	6719	4854	4415	3640	3953
1953	898	81	80	80	1101	611	5267	6470	6074	4854	4415	3640	2801
1954	898	81	80	80	1279	1925	6050	6650	5437	4854	4415	3640	2954
1955	1047	81	80	80	1101	171	598	4688	5153	4502	3839	3815	2101
1956	1015	81	80	2678	3172	6995	8235	8704	6457	4915	4366	3768	4207
1957	867	81	80	80	1101	1793	7571	9574	6485	5083	4759	3835	3450
1958	907	81	80	80	1101	359	9514	9494	5654	4855	4580	3892	3387
Mean	815	319	177	375	1302	978	4168	5825	5199	4719	4251	3258	2619

Table 177. Modified Mean Discharges in CFS, Boise River at Notus, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										340	455	659	0
1929	683	706	650	537	559	556	269	195	185	153	140	336	413
1930	504	602	550	496	458	424	190	112	111	94	62	277	323
1931	501	627	563	517	483	449	235	114	111	94	62	252	333
1932	488	739	777	784	831	833	353	195	210	228	260	403	508
1933	667	761	693	631	609	637	329	210	212	224	192	424	465
1934	634	728	660	598	573	528	279	193	195	176	143	373	423
1935	569	546	483	423	378	353	185	101	101	91	60	182	289
1936	488	773	787	951	939	1122	908	514	235	293	293	471	647
1937	556	645	582	520	486	434	215	132	131	114	81	309	350
1938	602	723	667	683	546	667	2454	4699	3160	358	325	487	1282
1939	709	886	813	751	742	681	992	276	235	228	260	403	580
1940	667	761	693	680	588	688	765	179	218	244	260	403	511
1941	678	748	659	696	710	559	276	337	689	633	602	750	610
1942	602	677	637	655	840	657	286	546	807	455	649	563	613
1943	766	733	811	3979	2795	2777	6682	4888	1153	1177	489	435	2219
1944	672	746	774	730	760	1431	1556	241	496	498	670	595	763
1945	475	571	641	631	769	698	331	260	513	472	636	533	551
1946	654	963	909	805	760	3239	5827	3255	1114	559	618	561	1607
1947	793	739	704	623	625	1948	1484	2006	1092	446	576	502	965
1948	829	849	763	735	710	680	1617	1125	1659	533	659	612	895
1949	790	817	735	589	796	665	1338	2185	513	602	611	583	853
1950	686	660	572	587	643	634	5358	1724	980	319	480	466	1088
1951	761	669	615	556	1270	4289	5936	3606	1894	343	410	390	1727
1952	867	603	593	4202	2405	3603	6511	4397	2428	509	405	696	2264
1953	603	709	603	655	668	1011	2356	2787	3079	265	366	422	1125
1954	650	654	554	460	627	2390	2827	2281	1602	291	382	481	1101
1955	707	666	563	514	452	447	213	1187	193	302	246	477	499
1956	774	755	706	3259	2621	6702	4655	4626	2349	398	413	624	2325
1957	870	792	652	559	818	2441	6709	5758	1901	337	405	664	1826
1958	1072	709	663	589	800	850	6314	4888	2121	385	431	748	1629
Mean	677	722	669	947	878	1413	2248	1768	990	361	373	481	960

Table 178. Modified Mean Discharges in CFS, Malheur River at Little Valley near Hope, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										50	10	0	0
1929	47	17	23	18	4	21	40	128	0	37	10	0	29
1930	0	0	33	23	9	15	40	137	13	55	24	18	31
1931	15	12	8	10	16	21	62	128	30	8	15	13	28
1932	41	12	10	11	75	124	61	138	17	47	10	13	47
1933	23	22	24	15	11	31	62	133	3	54	28	40	37
1934	31	20	41	39	13	7	40	158	34	33	15	40	39
1935	49	50	41	37	16	31	86	167	12	50	42	17	50
1936	10	3	8	36	297	182	94	158	42	55	21	27	77
1937	28	15	36	21	16	31	69	128	12	21	3	40	35
1938	80	17	163	102	88	598	513	137	2	37	18	27	149
1939	13	18	36	39	22	156	40	132	25	52	24	17	48
1940	16	17	36	39	310	234	995	156	12	63	15	67	161
1941	26	30	59	109	643	1636	976	281	15	67	34	29	323
1942	18	20	60	80	315	732	1418	257	27	80	47	40	256
1943	26	22	265	545	1773	1389	1798	454	20	54	15	25	523
1944	24	22	49	46	130	75	50	128	37	44	23	7	53
1945	20	20	42	122	193	101	371	467	25	62	34	18	123
1946	29	24	161	109	279	984	1450	273	37	72	36	29	289
1947	24	29	55	42	169	24	121	128	7	59	39	34	60
1948	31	25	49	73	14	16	50	137	27	68	28	25	46
1949	33	18	34	16	178	50	778	205	5	62	33	40	120
1950	18	17	41	37	126	94	345	128	18	37	23	15	74
1951	8	17	59	83	852	413	1210	138	18	54	26	13	235
1952	24	18	49	49	301	1854	3045	774	22	49	28	27	518
1953	20	18	42	203	836	405	363	515	583	54	31	24	253
1954	18	20	49	57	77	18	203	146	24	54	33	25	60
1955	20	20	42	44	18	20	59	128	5	41	13	20	36
1956	15	17	81	285	129	644	881	239	24	37	10	54	201
1957	28	25	59	39	1449	1424	1069	691	5	50	24	37	401
1958	28	20	50	122	1831	836	1733	1411	15	47	29	24	498
Mean	25	20	57	82	338	406	601	273	37	50	24	27	160

Table 179. Modified Mean Discharges in CFS, Payette River near Horseshoe Bend, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928	0	0	0	0	0	0	0	0	0	3317	3348	2749	0
1929	1219	829	777	766	782	1076	1949	3789	3899	3350	3353	2714	2049
1930	1137	650	1127	743	1045	1398	3462	3854	3160	3395	3359	2731	2178
1931	1211	788	725	769	737	1140	2306	3154	3136	3337	2725	1897	1834
1932	1078	585	603	600	650	1468	3911	7319	6173	3306	3436	2795	2664
1933	1244	862	800	681	777	902	2822	3974	11282	3289	3120	2879	2716
1934	1307	822	950	1294	1301	2377	4556	3424	3025	3449	3488	2833	2407
1935	1219	892	803	836	905	1037	3314	4696	4075	3397	3340	2844	2286
1936	1198	677	740	730	777	1088	5637	7530	4654	3345	3467	2877	2730
1937	1270	687	737	675	730	1065	2326	4455	3143	3432	3563	2857	2088
1938	1314	879	1532	1047	1121	2138	5249	7793	10989	3426	3397	2771	3474
1939	1946	1560	1550	1538	1519	1636	3817	4307	3112	3444	3419	2768	2557
1940	1255	736	919	989	1280	3189	5274	6032	4302	3459	3496	2786	2813
1941	1411	1067	1008	906	1097	1833	2943	4852	5958	3384	3384	2595	2542
1942	2021	1600	1857	1293	1193	1311	4512	5693	7489	3511	3447	2901	3073
1943	2062	1499	1111	1688	1456	2127	9779	9644	13183	6546	3345	2874	4611
1944	2244	1738	1759	1673	1563	1437	2119	3328	3065	3424	3506	2855	2397
1945	1280	871	761	855	1115	1275	2284	5501	5158	3445	3491	2902	2418
1946	1289	911	1034	1096	1036	2119	6529	10619	7887	3415	3478	2882	3534
1947	2037	1336	2089	1509	1449	2298	3533	10837	8106	3432	3569	2860	3602
1948	1945	1541	1663	1348	1581	1535	3170	6226	11763	3200	3418	2798	3343
1949	1919	1400	1506	1446	1108	1754	4400	8341	6669	3468	3459	2864	3205
1950	1083	938	829	997	1146	1896	4003	6060	12393	5003	3400	2817	3381
1951	2052	1477	1358	1328	1681	1514	6894	11065	8374	3520	3442	2842	3801
1952	1878	1403	1341	1459	1179	1312	7396	15504	10831	3273	3311	2882	4317
1953	1987	1592	1593	1366	1494	1550	3852	5484	13253	4787	3340	2820	3591
1954	1971	1410	1537	1312	1434	1948	4879	10364	8524	3785	3392	2845	3626
1955	1997	1561	1576	1589	1568	1374	1694	4784	5245	3249	3445	2817	2580
1956	1050	1131	2802	1911	1339	2156	7778	15254	11900	3382	3447	2914	4592
1957	1819	1452	1325	1769	1465	2372	4492	12431	11277	3800	3852	3170	4113
1958	1195	834	911	889	1524	1502	3749	12616	10144	3291	3416	2835	3584
Mean	1555	1124	1244	1170	1201	1661	4287	7299	7405	3619	3411	2807	3070

Table 180. Modified Mean Discharges in CFS, Payette River near Payette, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										1285	1382	1529	0
1929	1138	1227	1187	1106	1279	1561	1933	2748	2319	1415	1415	1479	1568
1930	1154	1008	1463	976	1586	1789	2958	2699	1294	1415	1415	1479	1602
1931	1252	1244	943	1106	1153	1659	2252	1740	1361	1398	1545	1496	1430
1932	1057	924	943	894	1130	2699	4790	6715	5361	1463	1463	1479	2409
1933	1154	1294	976	1057	1207	1593	2857	3008	8689	1415	1415	1479	2171
1934	1154	1277	1366	1837	1838	2634	4302	2032	1361	1415	1415	1479	1840
1935	1154	1244	1024	1171	1297	1415	3092	3317	2252	1415	1415	1479	1689
1936	1106	958	959	1057	1583	2032	6386	7138	3529	1236	1333	1496	2398
1937	1138	958	911	943	1099	1789	2991	3951	1529	1219	1317	1496	1615
1938	1138	1227	2390	2081	2198	4309	6756	7447	9781	1691	1366	1479	3485
1939	1902	1933	1902	1756	1748	2797	3781	2992	1344	1268	1366	1597	2033
1940	1154	958	1171	1415	2400	4081	6235	4959	2555	1333	1431	1664	2442
1941	1301	1479	1496	1301	1856	2276	2891	3675	4655	1317	1577	1613	2116
1942	1870	1882	2260	1886	2072	1919	4840	4911	6437	1382	1431	1529	2696
1943	1854	1899	2081	3057	2541	3366	11294	8211	12151	4813	1577	1496	4521
1944	1935	1983	1902	1935	1913	1821	2286	1870	1798	1268	1398	1496	1799
1945	1154	1260	1073	1350	2126	1951	2050	5301	3933	1366	1431	1529	2042
1946	1138	1143	1675	1593	1730	3577	6958	9789	6336	1366	1415	1597	3196
1947	1984	2067	2862	1854	1964	2813	3630	9984	6874	1317	1431	1580	3203
1948	1886	1849	1821	1789	1774	1772	3882	6569	10974	1350	1447	1580	3048
1949	1902	1765	1789	1772	1928	2634	4454	7463	5243	1317	1447	1445	2765
1950	1219	1412	1041	1480	2000	2976	4252	4764	11142	3171	1447	1496	3025
1951	1919	1983	1870	1821	2703	2195	7260	10146	7092	1577	1496	1563	3464
1952	1951	1748	2374	1919	2330	2341	9462	15610	10033	1642	1415	1563	4363
1953	1919	1899	1902	2488	2360	2244	4067	4748	12655	2976	1463	1479	3340
1954	1854	1916	1935	1902	2108	2520	4857	9496	7378	1951	1480	1580	3250
1955	1870	1983	1919	1919	1928	1984	2319	3837	3765	1366	1350	1479	2142
1956	1138	1563	3805	2894	1930	2878	7932	14585	10554	1366	1512	1529	4309
1957	2000	1983	1935	1837	2703	3902	5445	12341	9714	1317	1366	1546	3841
1958	1285	1244	1447	1480	2973	2098	4487	12390	9311	1252	1382	1529	3402
Mean	1490	1510	1681	1656	1914	2455	4690	6483	6047	1627	1432	1524	2707

Table 181. Observed Mean Discharges in CFS, Weiser River near Weiser, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										154	141	134	0
1929	104	146	161	154	180	1428	1699	1485	891	182	153	97	558
1930	42	81	242	124	978	950	1086	967	316	150	137	69	424
1931	73	101	109	138	254	1849	1254	798	178	153	138	55	427
1932	36	79	125	135	224	3478	3726	3621	1422	213	164	84	1112
1933	76	160	117	143	209	1527	3186	2493	1975	236	159	96	865
1934	75	136	667	1228	746	977	1385	574	244	148	153	94	535
1935	52	203	317	493	405	1343	2430	1906	649	154	148	94	683
1936	49	103	96	158	268	2119	3917	2689	781	169	161	92	883
1937	59	81	99	102	155	1520	1879	1532	566	179	164	111	539
1938	86	407	1519	850	2175	4325	3726	3634	2069	415	171	145	1623
1939	193	257	255	229	205	2793	1891	1265	313	167	154	106	656
1940	91	94	198	533	2675	3836	4101	1966	642	185	176	146	1212
1941	267	660	924	954	2092	2242	2012	1972	1321	319	215	182	1089
1942	213	257	1418	881	1676	1854	3324	2325	1555	270	233	202	1178
1943	145	329	972	2322	1258	3180	4835	2457	2121	527	197	183	1543
1944	202	276	200	164	428	1055	1627	1208	921	242	218	185	559
1945	101	287	164	444	2132	1725	1471	3195	2128	304	236	220	1025
1946	158	376	1057	685	483	4429	3620	2865	902	275	237	207	1281
1947	184	990	1595	376	1573	1467	1412	2102	1136	257	211	202	954
1948	226	282	296	810	870	1024	2751	3790	2076	298	223	222	1071
1949	190	207	211	179	883	3506	2376	2606	790	223	202	158	962
1950	150	192	159	272	1031	2977	2597	2356	1798	411	224	208	1029
1951	233	287	491	496	1800	1758	2855	2359	896	262	239	160	979
1952	411	627	1533	914	1838	2380	7764	4619	1859	463	242	299	1905
1953	298	163	215	2502	1636	1156	2170	2626	3175	556	247	188	1239
1954	140	202	319	987	1533	1314	2318	2320	1050	304	234	155	901
1955	158	182	151	156	159	592	2057	2393	1563	402	241	183	687
1956	137	299	2920	2049	1270	2037	2761	2800	1324	337	255	190	1368
1957	358	360	494	224	1838	4065	2941	4317	1576	304	283	188	1411
1958	167	166	410	392	3712	2114	3183	4276	1860	328	276	210	1407
Mean	156	266	581	637	1155	2168	2745	2451	1270	281	203	158	1004

Table 182. Modified Mean Discharges in CFS, Snake River at Weiser, Idaho

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										10164	9647	11166	0
1929	12657	14156	12484	12345	12187	16193	13920	12623	12423	9057	8919	9828	12230
1930	10345	9921	10548	8673	16088	12715	13512	12676	9660	8902	9559	10438	11048
1931	10980	10121	9772	10125	9649	12042	11193	9377	8233	7519	8148	9196	9697
1932	9291	9907	9789	9571	9577	17764	17872	19499	16414	9099	8802	10184	12316
1933	10738	10796	9969	9572	9555	12006	14430	14068	19102	8541	8967	10220	11490
1934	11031	11119	11385	12613	11200	11284	12487	9621	8366	8260	8436	8958	10392
1935	10071	10015	9710	10047	9267	10141	14732	12075	10974	8971	8984	9722	10392
1936	10112	9954	9631	10525	11862	13668	22886	19379	14499	8837	9519	10648	12611
1937	10975	10447	10104	9489	9569	11375	13164	12582	10272	8615	9060	10321	10500
1938	11234	11166	13671	11847	12968	17852	22979	27902	24187	12075	9784	10791	15541
1939	12867	12206	11697	12940	15142	19658	18535	12628	9507	9002	9416	10885	12857
1940	11270	10426	10428	10865	14497	19180	20438	14832	10739	8928	9270	11601	12691
1941	11904	11788	11678	11676	14476	15673	14431	14057	16601	9884	11067	11957	12912
1942	12616	12650	13533	11920	13236	13171	19782	17948	20130	10211	10317	11805	13926
1943	12629	13374	14252	23122	22137	29045	51996	28416	25858	17543	11094	11949	21739
1944	16361	15846	14974	15850	15104	16011	14379	12006	13389	9798	10626	11687	13830
1945	11972	11912	10741	11312	15960	15727	12865	20172	17668	10688	10789	12203	13479
1946	13210	11613	15582	16772	15823	30679	39161	30961	18527	10758	10858	12660	18892
1947	13775	13119	16683	13554	17706	20866	18833	25759	19932	10340	10727	12152	16110
1948	13224	12302	14722	14660	15920	16548	16367	21154	23387	11057	10694	12159	15171
1949	14800	11806	12070	14598	14939	24351	28520	26003	15646	9792	10317	11517	16201
1950	12015	11546	10471	12228	15950	22423	32765	18896	23098	13623	10707	11880	16265
1951	16722	16924	16676	16057	26793	24972	42949	29278	20784	10836	11628	12193	20403
1952	17834	16068	17479	20013	20421	26403	64285	49582	25086	13123	11021	12944	24491
1953	15893	14734	12200	19984	17686	17496	19645	20678	32498	13000	10977	12532	17246
1954	13458	12645	12774	14985	17636	20579	27834	23052	20643	10894	10912	12001	16422
1955	13211	12405	11769	12140	15310	15314	12831	15660	13354	10423	10185	11406	12818
1956	12070	12020	17670	18242	18821	28707	39281	36806	29397	10795	11535	12621	20646
1957	16665	15727	15262	15645	21056	27842	31012	38813	28021	10665	11154	13006	20385
1958	16941	14803	15091	14553	23584	21008	31854	37744	23564	10671	11663	12941	19489
Mean	12898	12383	12763	13534	15459	18694	23831	21479	18065	10399	10173	11413	15074

Table 183. Observed Mean Discharges in CFS, Burnt River near Hereford, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										72	67	42	0
1929	29	0	0	0	0	80	187	128	67	72	67	42	56
1930	29	0	0	0	0	83	86	39	67	72	67	42	41
1931	29	0	0	0	0	0	173	42	67	72	67	42	41
1932	29	0	0	0	0	0	545	223	67	72	67	42	87
1933	29	0	0	0	0	0	262	315	67	72	67	42	72
1934	29	0	0	0	0	46	40	39	67	72	67	42	34
1935	29	0	0	0	0	0	153	75	67	72	67	42	42
1936	29	0	0	0	0	0	370	81	67	72	67	42	60
1937	29	0	0	0	0	0	89	96	67	72	67	42	39
1938	29	0	0	0	0	0	511	176	67	72	67	42	80
1939	11	7	7	2	0	62	213	104	67	70	76	42	55
1940	20	12	8	5	0	59	224	117	72	60	88	34	58
1941	7	8	8	8	43	166	170	140	97	88	91	35	72
1942	67	40	67	65	56	94	392	187	114	111	88	79	113
1943	23	12	31	55	115	185	617	244	165	120	112	103	148
1944	28	52	60	7	2	2	15	104	42	89	88	71	47
1945	8	3	5	2	2	47	170	133	134	76	111	76	64
1946	37	8	7	10	52	172	430	177	128	99	122	91	111
1947	42	24	39	72	41	11	185	146	118	91	94	91	80
1948	20	10	44	47	19	18	259	296	225	117	104	104	105
1949	81	27	28	47	59	169	341	193	119	89	114	99	114
1950	76	45	33	33	36	60	240	172	128	99	99	94	93
1951	55	39	47	28	38	145	392	153	106	81	104	74	105
1952	37	30	31	34	43	111	548	132	138	130	111	91	119
1953	62	25	29	33	40	93	230	268	326	124	122	96	121
1954	93	64	46	31	20	16	81	128	81	78	109	94	70
1955	68	34	24	26	11	2	0	88	114	63	93	12	45
1956	3	3	3	65	83	249	516	272	138	107	122	67	136
1957	34	22	16	10	7	117	393	250	131	135	107	54	107
1958	7	15	34	50	74	197	469	393	139	109	135	92	143
Mean	36	16	19	21	25	73	277	164	109	88	92	64	82

Table 184. Modified Mean Discharges in CFS, Powder River near Robinette, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928										237	68	86	0
1929	117	163	151	177	164	798	570	685	997	195	46	45	343
1930	78	123	171	102	308	270	412	489	407	81	34	47	209
1931	112	121	125	132	186	366	548	743	338	49	26	22	231
1932	50	114	154	128	179	1002	1301	1593	1385	359	101	101	539
1933	132	193	179	174	119	325	817	1172	2287	442	133	111	507
1934	111	208	228	304	213	327	613	501	235	68	33	32	239
1935	81	161	171	137	141	159	613	769	723	154	62	45	268
1936	57	109	81	93	136	304	1296	1312	528	114	65	54	345
1937	72	79	93	63	90	236	518	824	714	158	78	57	249
1938	117	182	343	270	523	972	1423	1616	1560	472	124	114	642
1939	143	176	189	140	123	898	1003	872	398	158	54	44	351
1940	88	131	141	185	384	696	1380	950	783	166	62	198	429
1941	267	303	278	382	611	977	1207	1358	1676	454	151	215	655
1942	246	398	680	424	721	584	1845	1787	1415	546	141	118	740
1943	151	203	229	761	611	966	1975	1434	1566	1088	185	155	776
1944	207	264	159	143	155	380	634	673	702	172	93	72	304
1945	98	178	128	193	438	442	768	140	1439	390	102	116	366
1946	145	161	390	247	283	987	1728	1997	1318	434	146	188	670
1947	195	313	291	190	683	551	709	1254	998	223	98	106	465
1948	241	227	213	280	322	446	1025	2158	2963	436	182	146	718
1949	218	215	236	137	362	1221	1286	2229	997	224	81	72	608
1950	140	173	146	141	303	593	739	800	1813	657	140	138	481
1951	215	229	301	293	506	553	1427	1685	787	301	106	103	541
1952	207	197	218	252	490	860	2573	2509	1612	571	135	151	813
1953	143	173	166	415	596	595	1069	1590	2944	1106	254	163	766
1954	236	200	189	249	369	420	618	872	765	333	143	128	376
1955	158	180	161	161	148	164	381	689	987	327	88	101	295
1956	145	212	395	655	447	993	1894	2725	1923	426	176	158	846
1957	198	173	169	239	632	993	1225	2325	1575	280	120	109	669
1958	169	205	301	312	991	748	1659	3579	2302	473	138	139	916
Mean	151	192	223	246	374	628	1108	1378	1271	362	110	108	512

Table 185. Modified Mean Discharges in CFS, Snake River below Pine Creek at Oxbow, Oregon

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1928	0	0	0	0	0	0	0	0	0	9989	9291	10652	0
1929	12278	15141	14058	18671	17661	22062	17236	12652	9998	5460	9106	11899	13824
1930	12839	12857	14567	16190	17241	15575	7065	9171	6422	5538	10028	12280	11624
1931	13270	12897	15445	16707	14935	16151	9077	4998	5000	5138	10107	10668	11189
1932	11730	13159	15317	15684	13676	21740	16498	16219	12937	6167	8971	11799	13660
1933	12613	13734	14571	17406	15249	16496	12483	12491	19828	5782	9151	11410	13410
1934	12236	13270	14801	20426	16169	15775	8753	5972	5000	4998	8252	10381	11319
1935	10706	11600	13551	17466	14519	14406	11215	7592	7657	5350	8876	10771	11124
1936	10985	12252	13410	15707	18767	17784	25728	16569	12647	5450	9476	11690	14167
1937	12506	13561	13922	17146	16769	16476	13914	6089	7867	5576	9523	12292	12101
1938	12871	12598	17491	19797	18481	22894	30975	26457	25278	9782	9549	10610	18043
1939	13306	14240	15081	17917	15609	22252	20799	10241	6758	6169	9533	12310	13671
1940	12566	12991	14551	18866	19386	22164	20408	14031	8578	5963	9275	13604	14344
1941	13455	14440	15717	19748	19822	20995	12284	11720	15208	6691	11517	12112	14443
1942	12956	14050	18460	20055	19723	18405	21164	18779	20508	7293	9602	12391	16076
1943	12935	14791	17470	21837	31649	33933	68718	27888	27138	15850	10288	11470	24373
1944	14205	15090	15821	18866	20735	19675	16031	6867	19231	4998	9723	12015	14392
1945	13215	13862	15497	16071	17373	17665	13505	17855	21977	6489	9880	12146	14598
1946	13997	13243	17382	23294	24998	36164	46929	26418	15208	6893	9515	12341	20480
1947	14224	15530	18650	21276	21854	23540	25369	17549	15028	5938	9345	11820	16632
1948	12855	14890	16681	21135	17874	19075	17604	23878	29247	7093	9254	11900	16768
1949	14754	14430	15891	18896	20292	23520	30894	22538	12418	6455	9749	11741	16764
1950	13185	12320	13941	20166	21694	22640	35089	14971	22967	11291	10428	12070	17497
1951	16434	16631	19250	23045	28969	28475	47398	30356	17638	7473	10938	11810	21454
1952	15424	15280	20800	23966	24513	34214	72257	50772	23407	9811	10078	12423	26037
1953	13470	13440	15211	23766	20723	22408	20729	16229	35037	9452	9995	11850	17640
1954	13945	13991	15650	20036	20063	22395	25780	16600	16658	7333	9727	11260	16079
1955	13766	13640	15050	18486	16079	14257	14581	10673	11168	6922	9901	10872	12929
1956	12985	13971	21772	23675	24201	30260	47327	32556	29458	8062	11158	15120	22495
1957	15935	15660	17460	19356	23912	25263	41437	41624	28338	7512	10808	12984	21642
1958	16255	15430	17421	20636	24629	24606	42701	36055	23528	10920	11830	13120	21376
Mean	13399	13966	16166	19547	19907	22047	26464	18864	17071	7262	9853	11972	16338

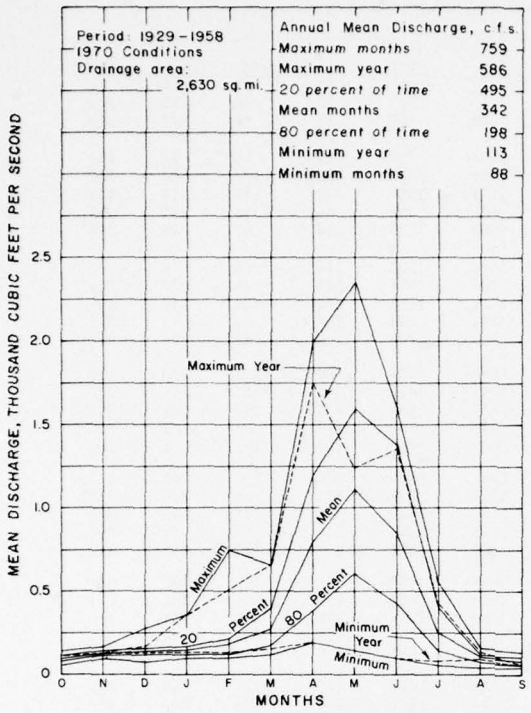


Figure 310 Monthly discharge, Bruneau River nr. Hot Spring, Ida.

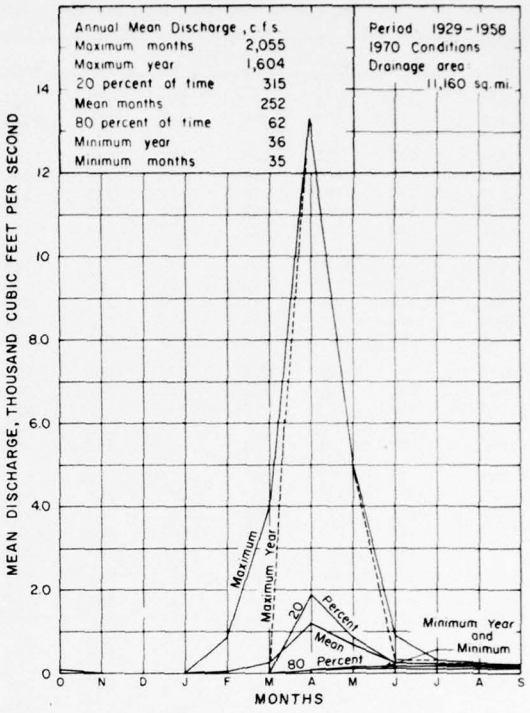


Figure 311 Monthly discharge, Owyhee River below Owyhee Dam, Oregon.

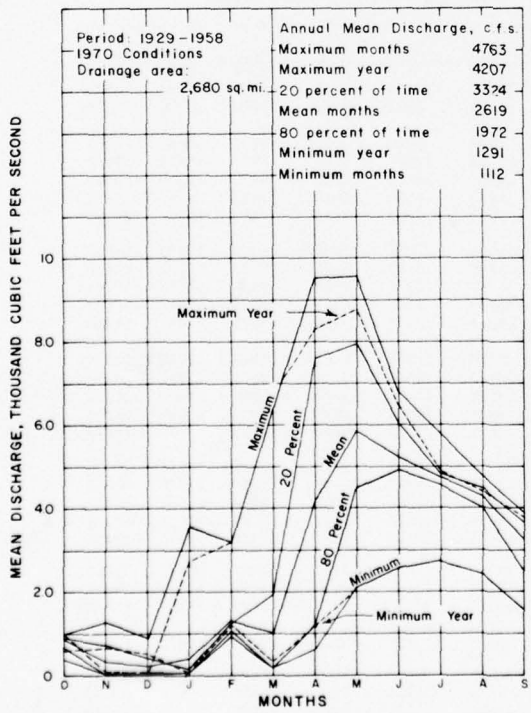


Figure 312 Monthly discharge, Boise River nr. Boise, Ida.

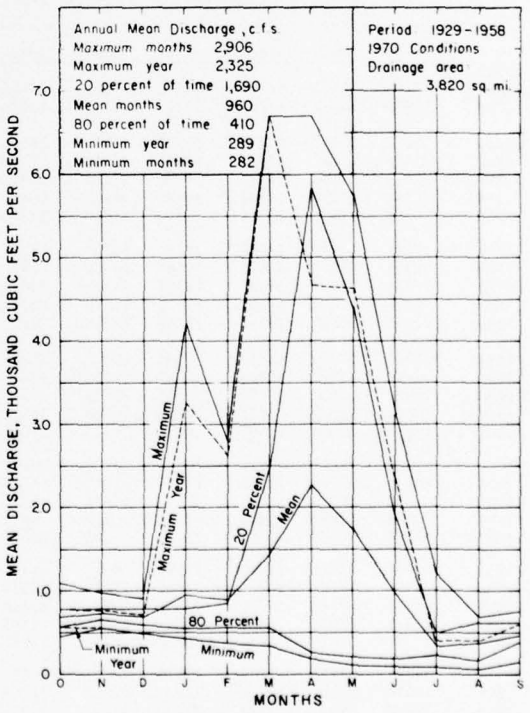


Figure 313 Monthly discharge, Boise River at Notus, Idaho.

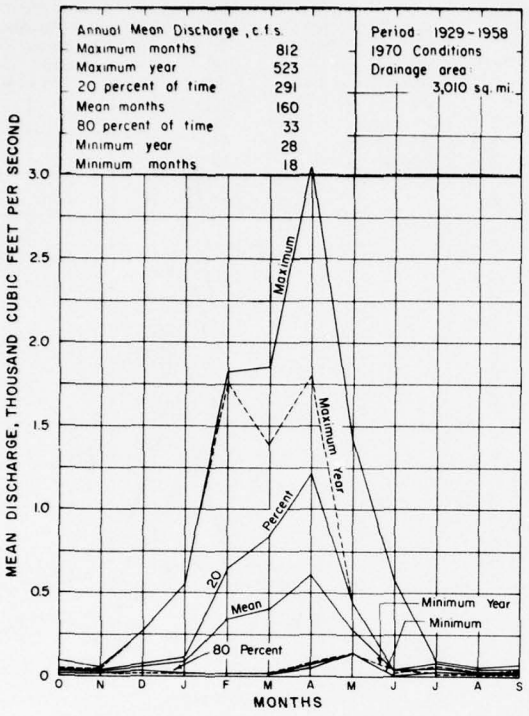


Figure 314 Monthly discharge, Malheur River at Little Valley nr. Hope, Oregon.

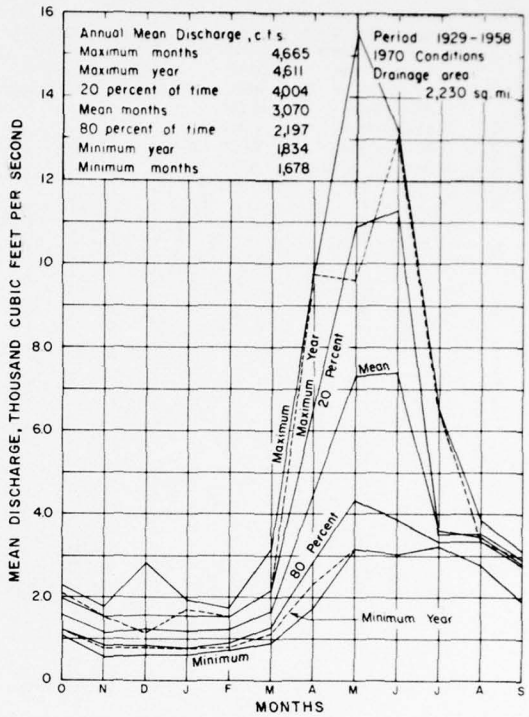


Figure 315 Monthly discharge, Payette River near Horseshoe Bend, Idaho.

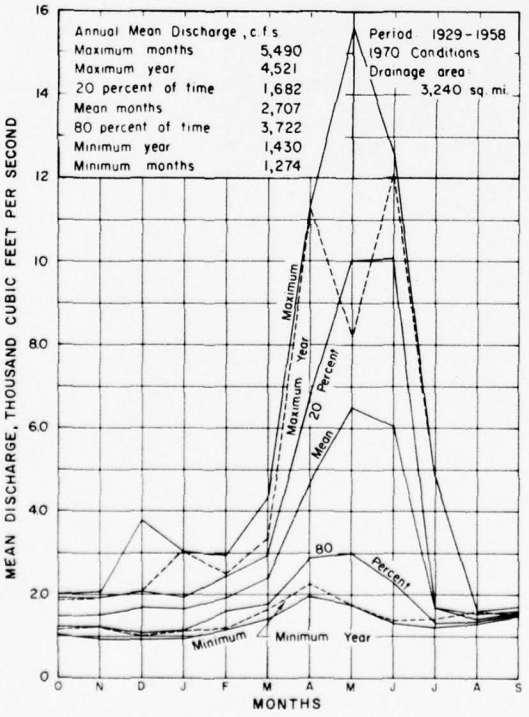


Figure 316 Monthly discharge, Payette River near Payette, Ida.

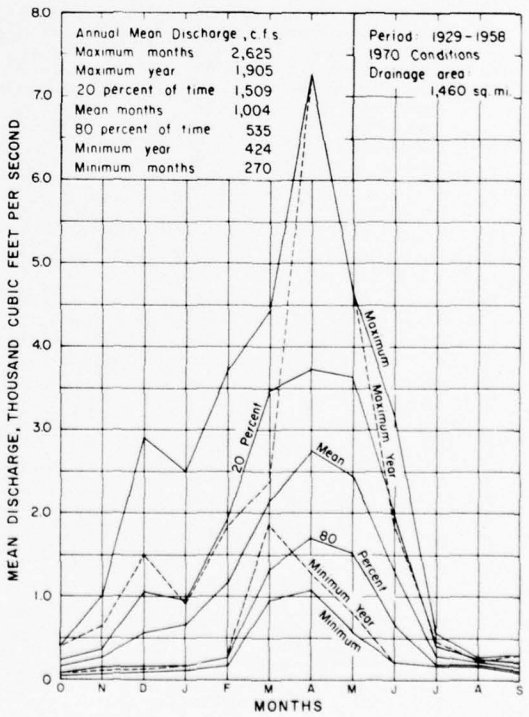


Figure 317 Monthly discharge, Weiser River near Weiser, Idaho.

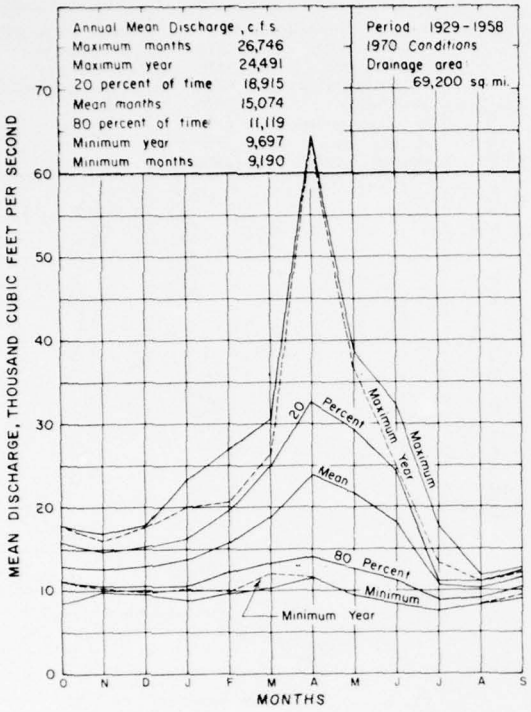


Figure 318 Monthly discharge, Snake River at Weiser, Ida.

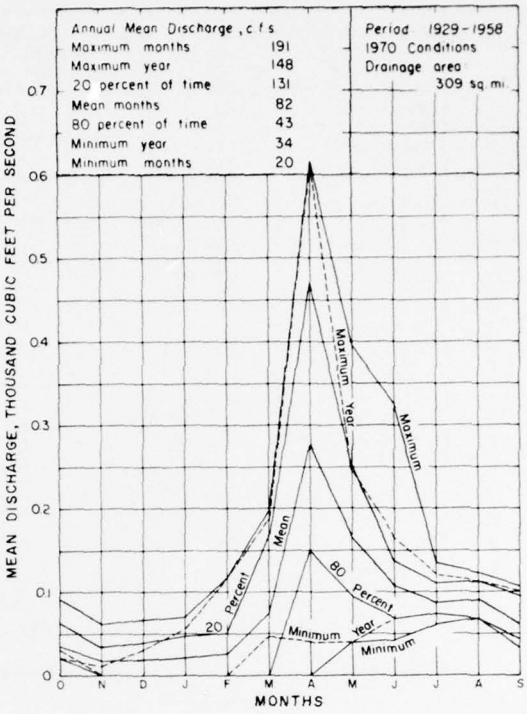


Figure 319 Monthly discharge, Burnt River near Hereford, Oregon

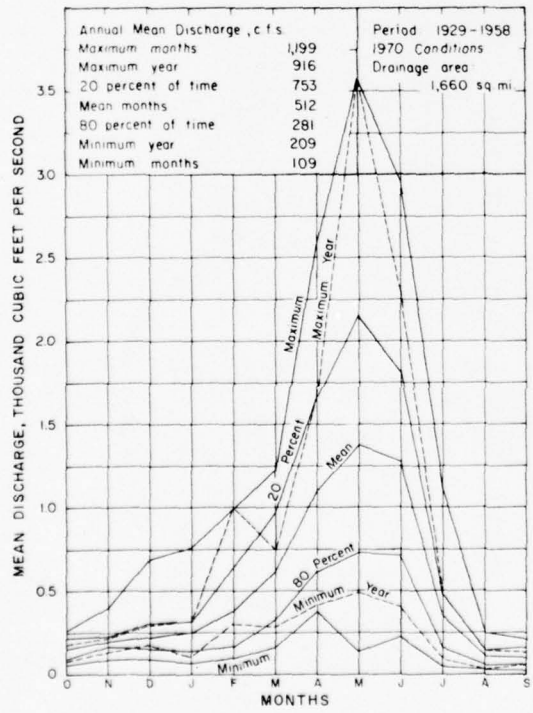


Figure 320 Monthly discharge, Powder River near Robinette, Oregon.

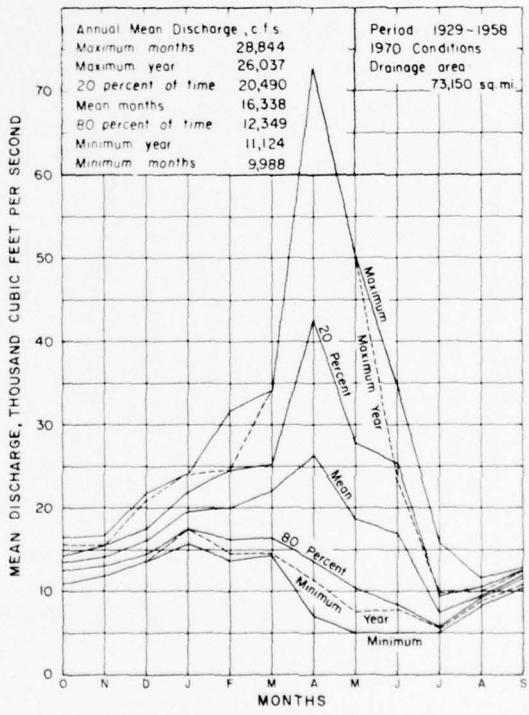


Figure 321 Monthly discharge, Snake River below Pine Creek at Oxbow, Oregon.

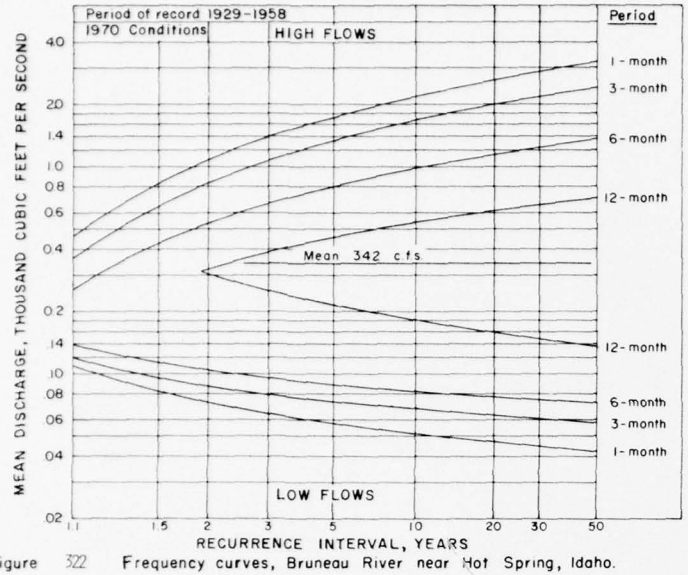


Figure 322 Frequency curves, Bruneau River near Hot Spring, Idaho.

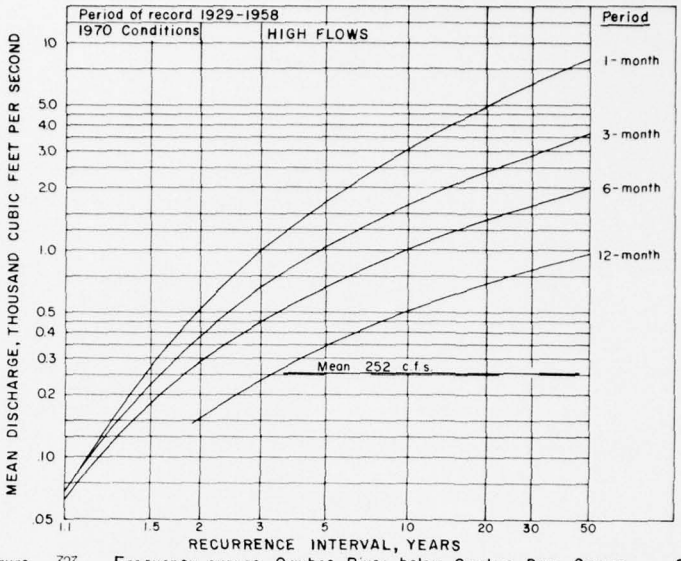


Figure 323 Frequency curves, Owyhee River below Owyhee Dam, Oregon. Sh. 1 of 2

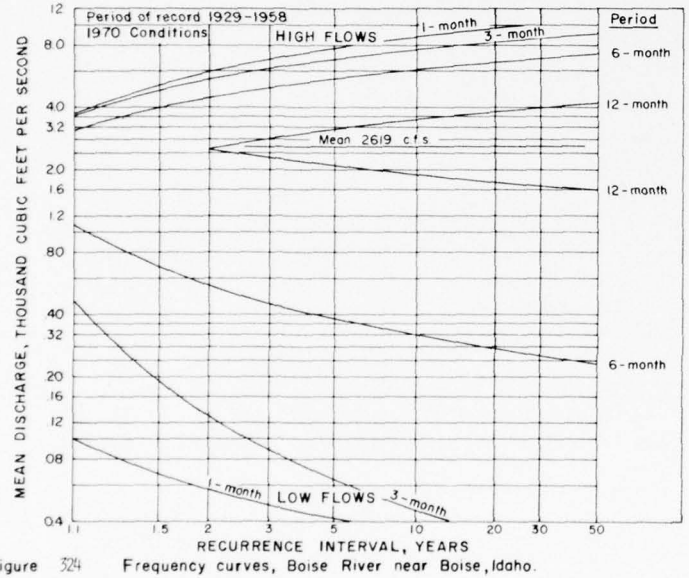


Figure 324 Frequency curves, Boise River near Boise, Idaho.

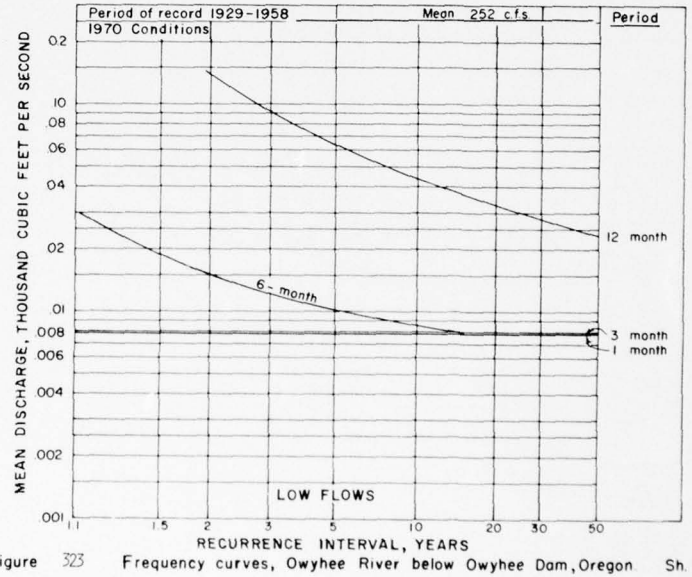


Figure 323 Frequency curves, Owyhee River below Owyhee Dam, Oregon Sh. 2 of 2

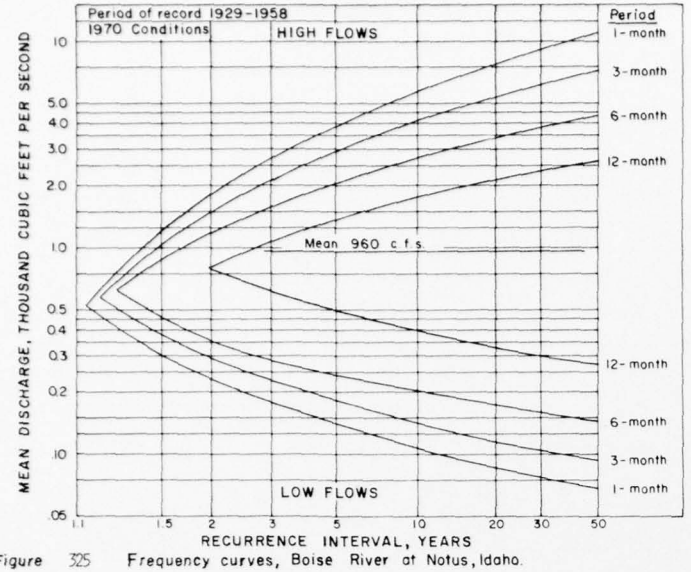


Figure 325 Frequency curves, Boise River at Notus, Idaho.

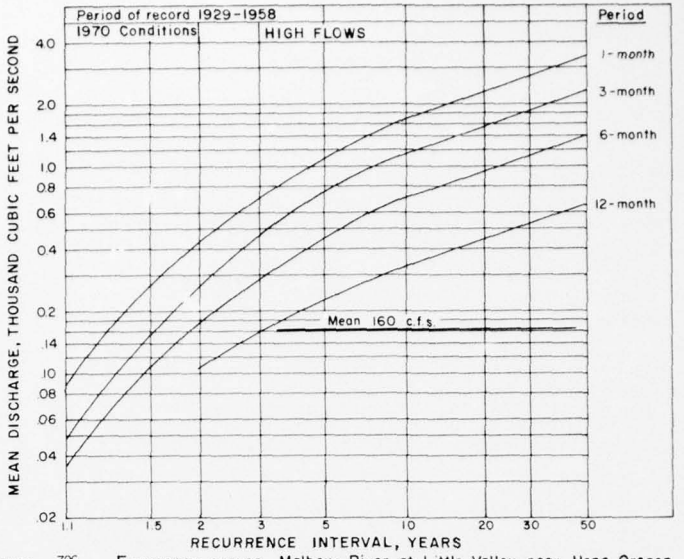


Figure 326 Frequency curves, Malheur River at Little Valley near Hope, Oregon. Sh. 1 of 2

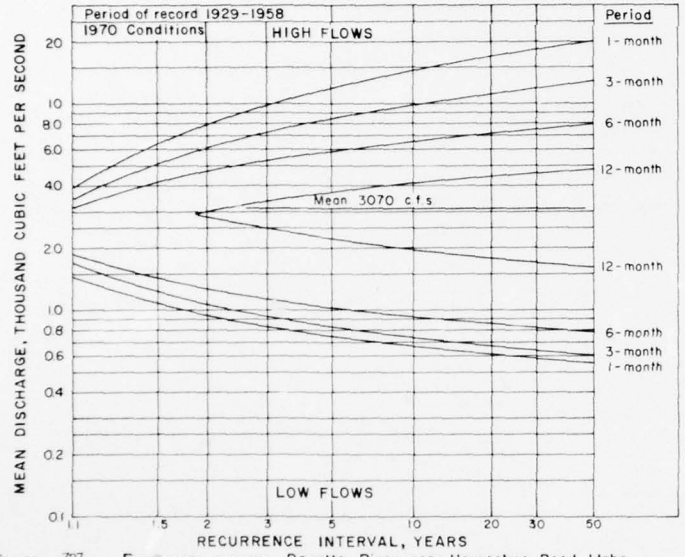


Figure 327 Frequency curves, Payette River near Horseshoe Bend, Idaho.

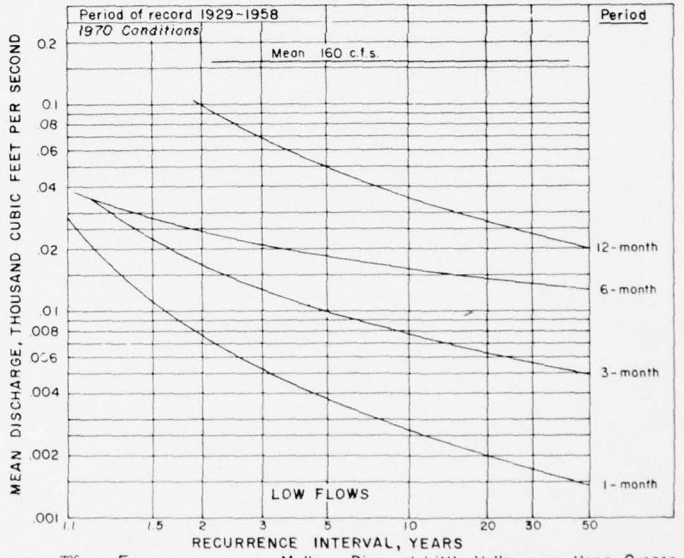


Figure 326 Frequency curves, Malheur River at Little Valley near Hope, Oregon. Sh. 2 of 2

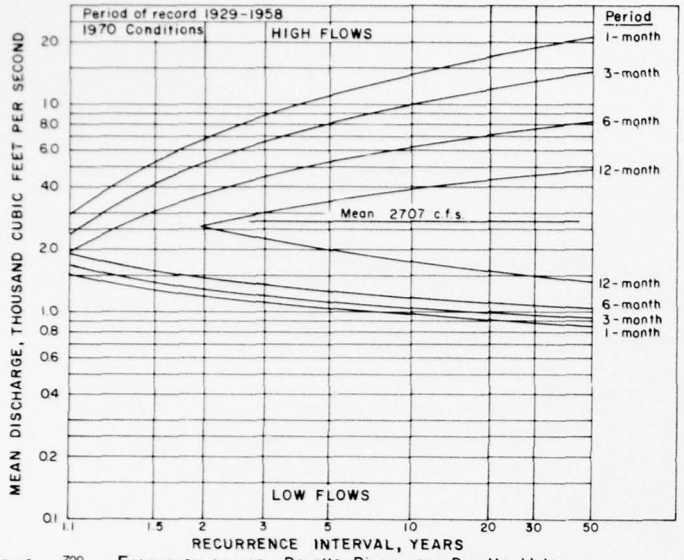


Figure 328 Frequency curves, Payette River near Payette, Idaho.

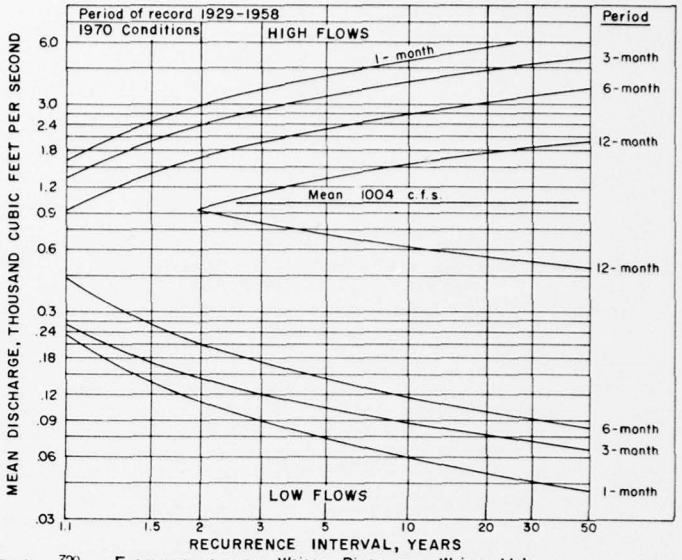


Figure 329 Frequency curves, Weiser River near Weiser, Idaho.

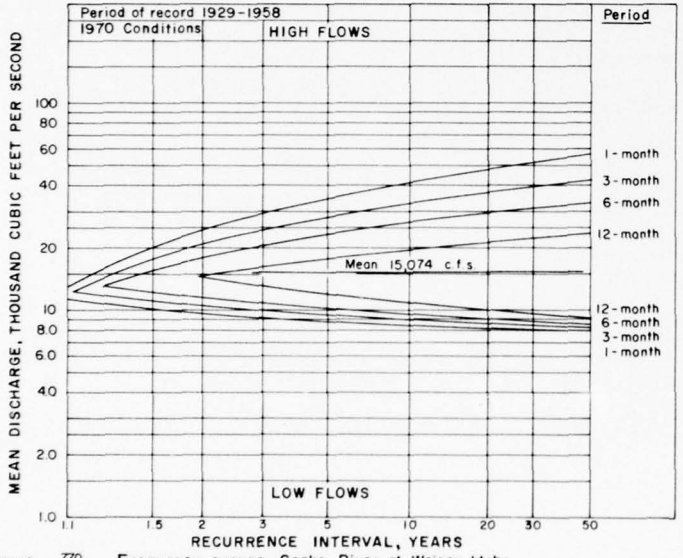


Figure 330 Frequency curves, Snake River at Weiser, Idaho

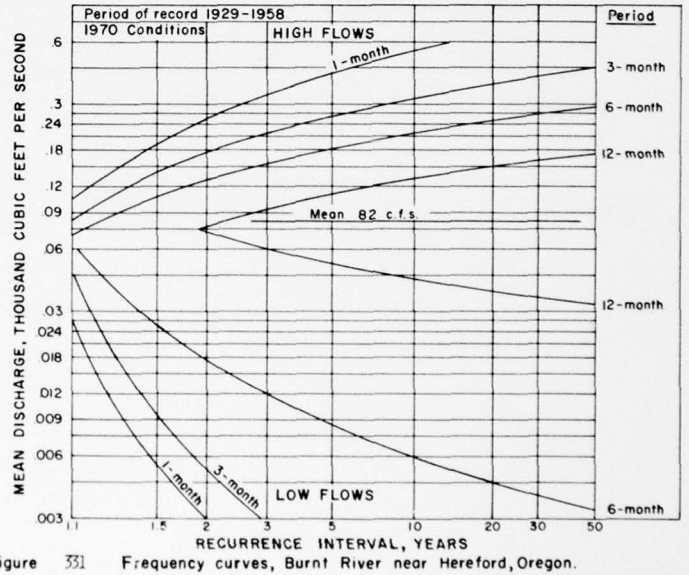


Figure 331 Frequency curves, Burnt River near Hereford, Oregon.

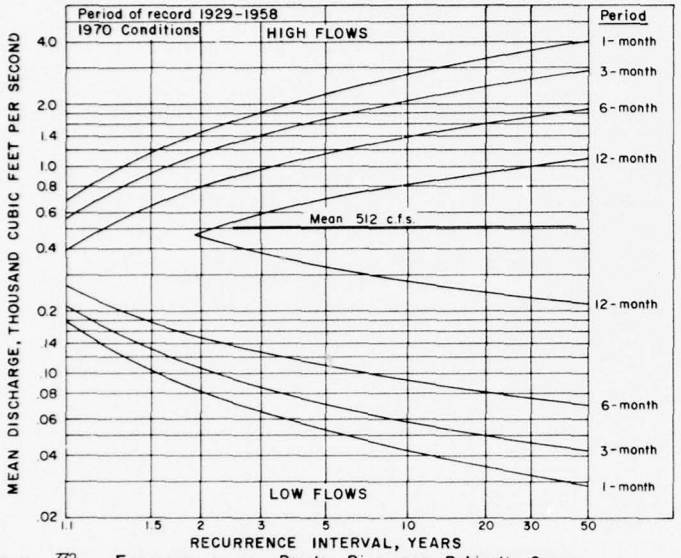


Figure 332 Frequency curves, Powder River near Robinette, Oregon.

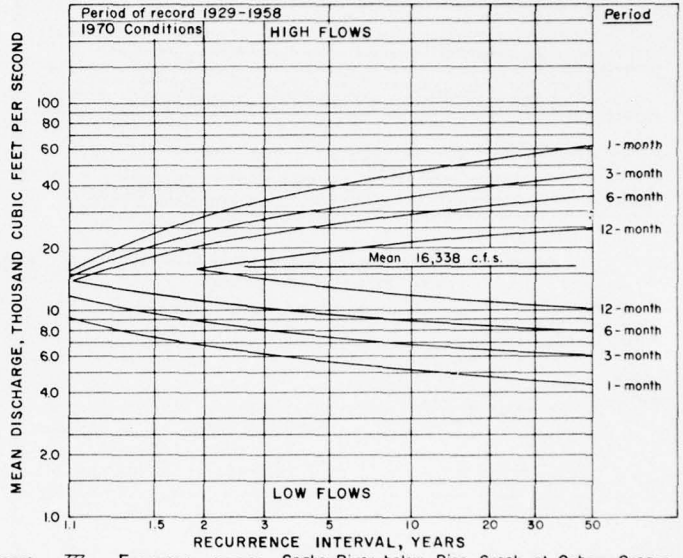


Figure 333 Frequency curves, Snake River below Pine Creek at Oxbow, Oregon.

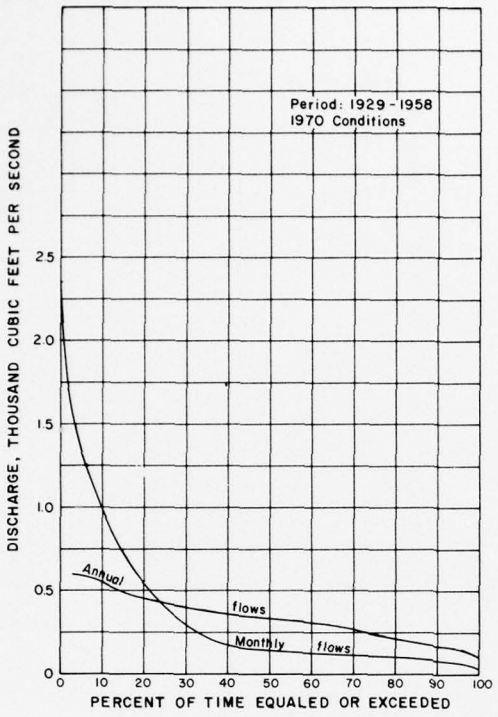


Figure 334 Duration curves, Bruneau River near Hot Spring, Idaho.

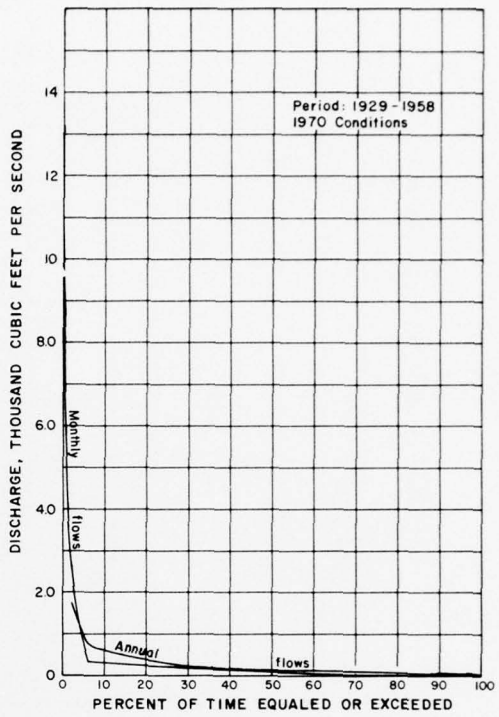


Figure 335 Duration curves, Owyhee River below Owyhee Dam, Oregon.

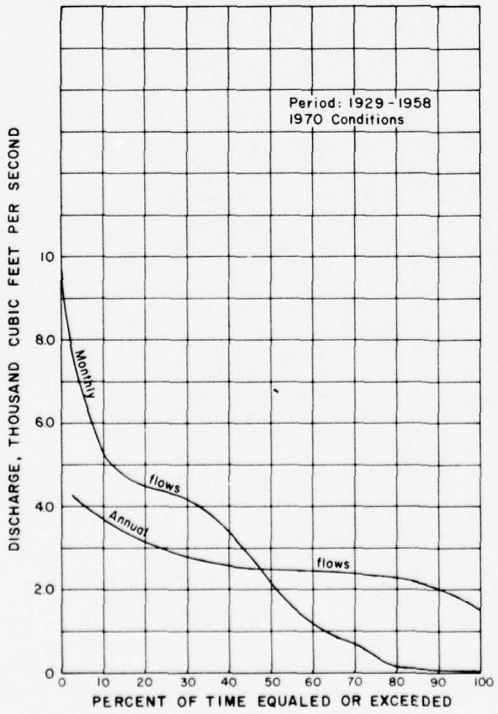


Figure 336 Duration curves, Boise River near Boise, Idaho.

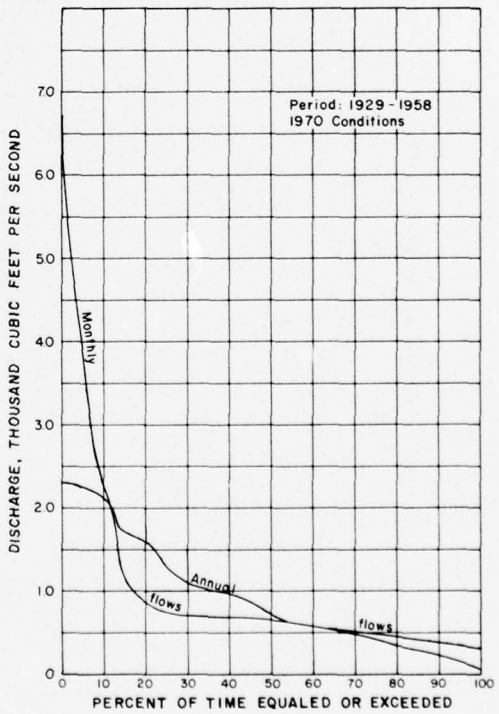


Figure 337 Duration curves, Boise River at Notus, Idaho.

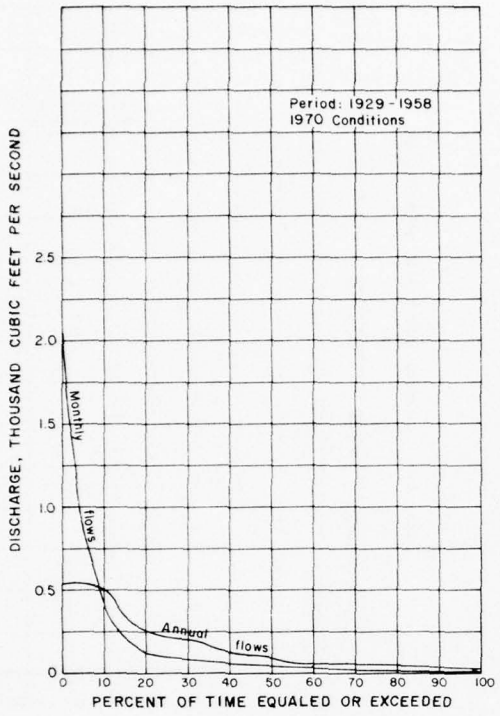


Figure 338 Duration curves, Malheur River at Little Valley near Hope, Oregon.

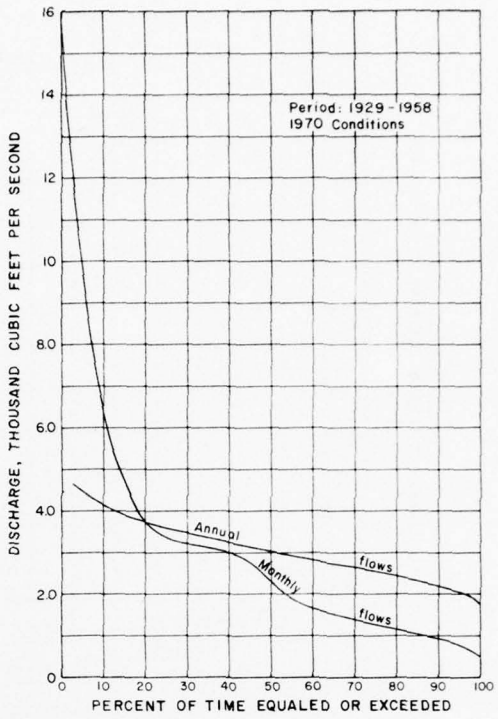


Figure 339 Duration curves, Payette River near Horseshoe Bend, Idaho.

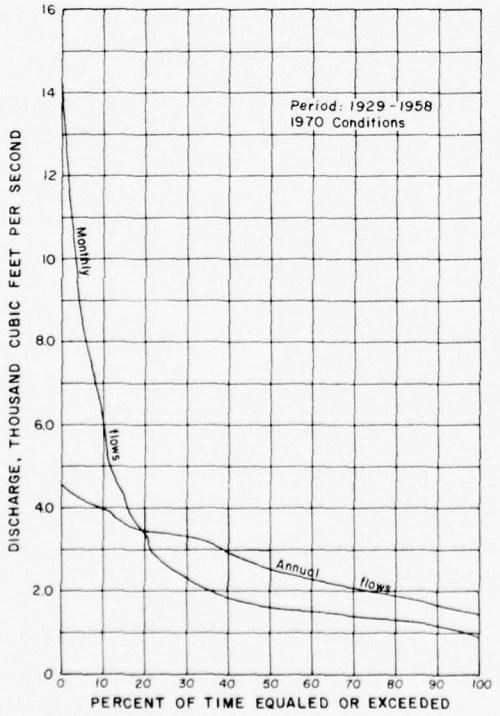


Figure 340 Duration curves, Payette River near Payette, Idaho

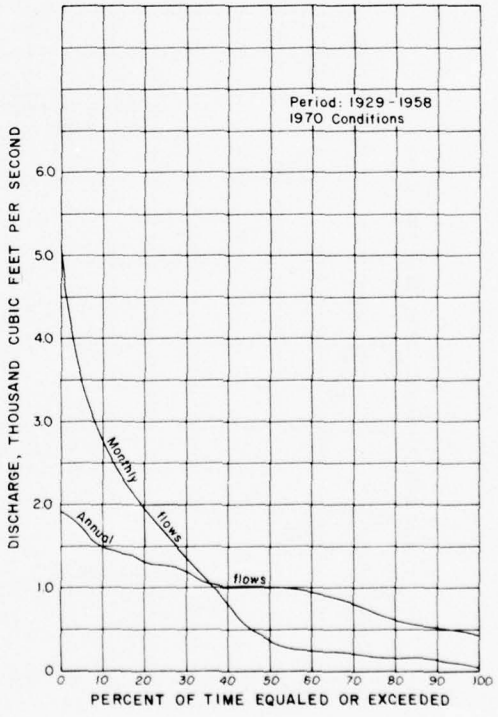


Figure 341 Duration curves, Weiser River near Weiser, Idaho.

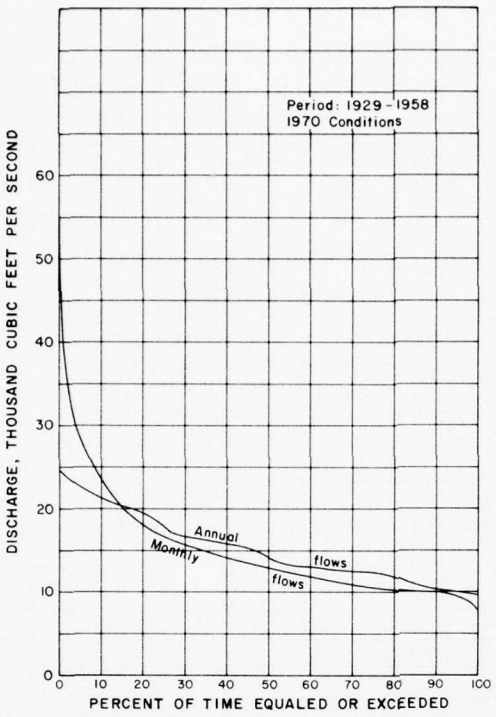


Figure 342 Duration curves, Snake River at Weiser, Idaho.

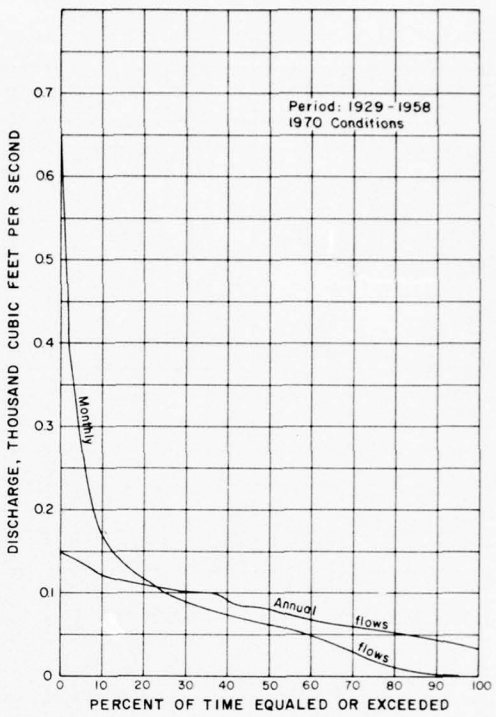


Figure 343 Duration curves, Burnt River near Hereford, Oregon.

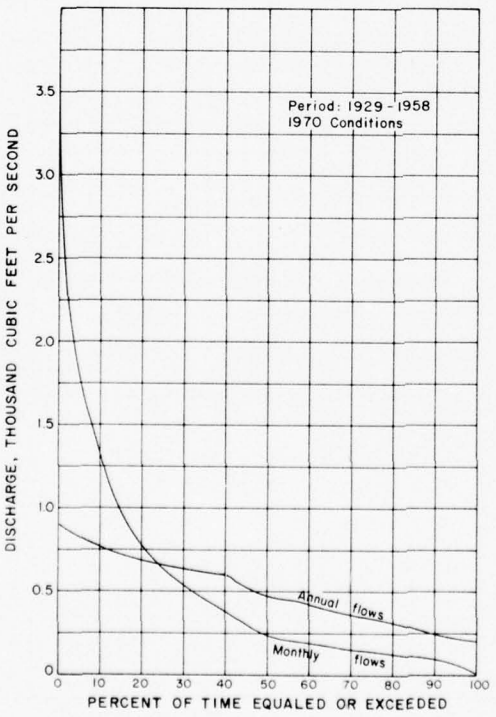


Figure 344 Duration curves, Powder River near Robinette, Oregon.

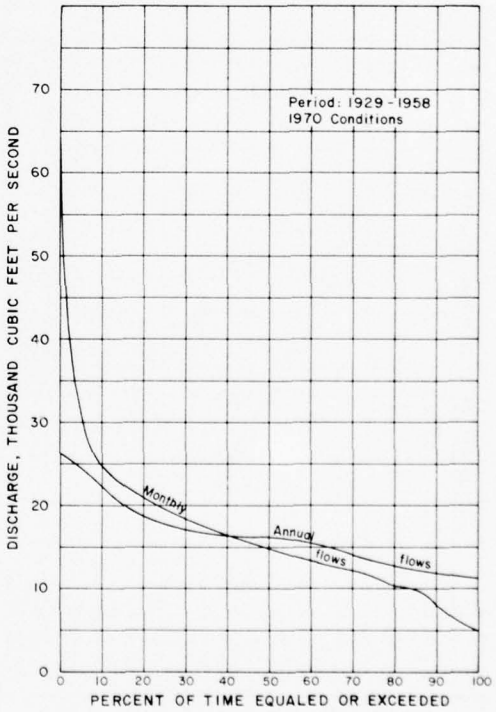


Figure 345 Duration curves, Snake River below Pine Creek at Oxbow, Oregon.

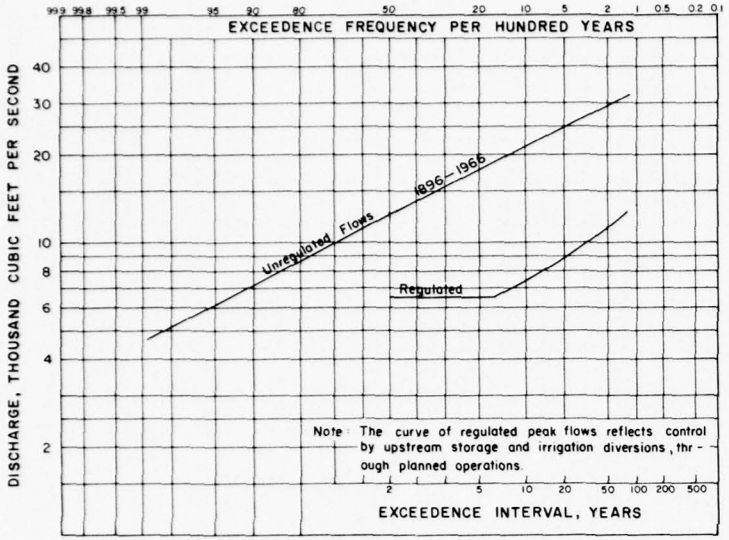


Figure 346 Frequency curve of annual peak flows, Boise River near Boise, Idaho

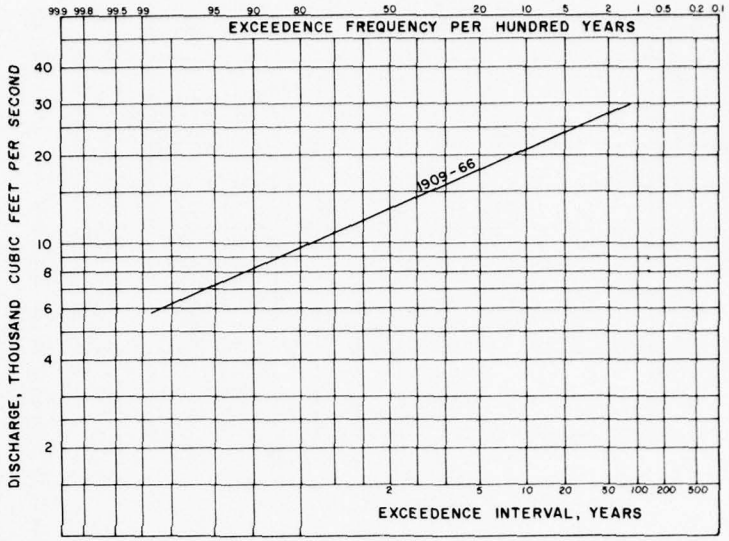


Figure 347 Frequency curve of annual peak flows, Payette R. nr. Horseshoe Bend, Idaho

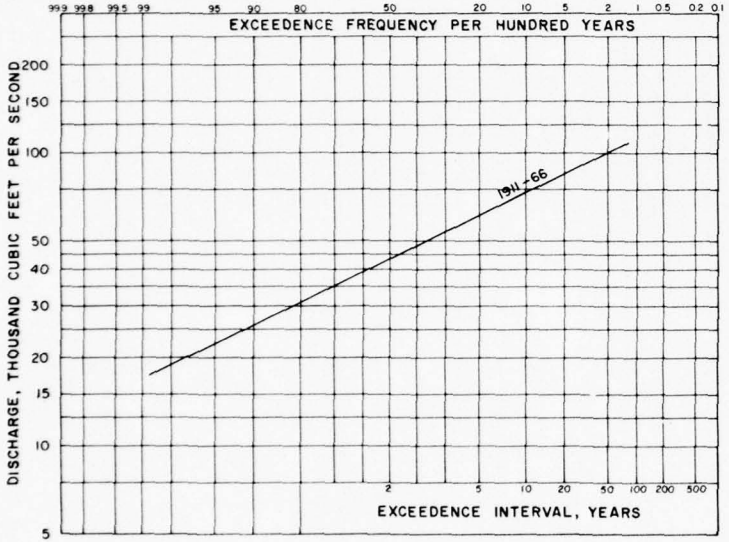


Figure 348 Frequency curve of annual peak flows, Snake River at Weiser, Idaho

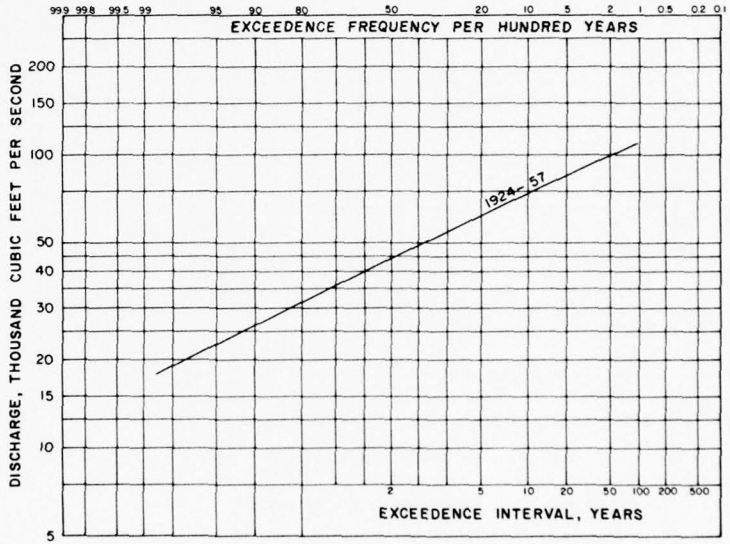


Figure 349 Frequency curve of annual peak flows, Snake River at Oxbow, Oregon

Table 186. Dependable Yield, Bruneau River near Hot Springs, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	113	33.0
2	1930-31	160	46.8
3	1929-31	210	61.4
4	1931-34	238	69.6
5	1930-34	226	66.1
6	1930-35	238	69.6
7	1929-35	248	72.5
8	1930-37	246	71.9
9	1929-37	253	74.0
10	1930-39	264	77.2
30	1929-58	342	100.0

Table 187. Dependable Yield, Owyhee River below Owyhee Dam, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	36	14.3
2	1930-31	44	17.5
3	1930-32	67	26.6
4	1931-34	60	23.8
5	1930-34	58	23.0
6	1930-35	68	27.0
7	1929-35	78	31.0
8	1930-37	102	40.5
9	1929-37	107	42.4
10	1929-38	142	56.3
30	1929-58	252	100.0

Table 188. Dependable Yield, Boise River near Boise, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	1,291	49.3
2	1930-31	1,616	61.7
3	1929-31	1,795	68.5
4	1931-34	1,910	72.9
5	1930-34	1,916	73.2
6	1930-35	1,944	74.2
7	1929-35	1,974	75.4
8	1930-37	2,000	76.4
9	1929-37	2,017	77.0
10	1929-38	2,111	80.6
30	1929-58	2,619	100.0

Table 189. Dependable Yield, Boise River at Notus, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1935	289	30.1
2	1930-31	328	34.2
3	1929-31	356	37.1
4	1929-32	394	41.0
5	1929-33	408	42.5
6	1939-35	390	40.6
7	1929-35	393	40.9
8	1930-37	417	43.4
9	1929-37	417	43.4
10	1929-38	503	52.4
30	1929-58	960	100.0

Table 190. Dependable Yield, Malheur River at Little Valley near Hope, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	28	17.5
2	1930-31	30	18.8
3	1929-31	29	18.1
4	1929-32	34	21.2
5	1929-33	35	21.9
6	1929-34	35	21.9
7	1929-35	37	23.1
8	1929-36	42	26.2
9	1929-37	42	26.2
10	1929-38	52	32.5
30	1929-58	160	100.0

Table 191. Dependable Yield, Payette River near Horseshoe Bend, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	1,834	59.7
2	1930-31	2,006	65.3
3	1929-31	2,020	65.8
4	1929-32	2,181	71.0
5	1929-33	2,288	74.5
6	1929-34	2,308	75.2
7	1929-35	2,305	75.1
8	1929-36	2,358	76.8
9	1929-37	2,328	75.8
10	1929-38	2,443	79.6
30	1929-58	3,070	100.0

Table 192. Dependable Yield, Payette River near Payette, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	1,430	52.8
2	1930-31	1,516	56.0
3	1929-31	1,533	56.6
4	1929-32	1,752	64.7
5	1929-33	1,836	67.8
6	1929-34	1,837	67.9
7	1929-35	1,815	67.0
8	1929-36	1,888	69.7
9	1929-37	1,858	68.6
10	1929-38	2,021	74.6
30	1929-58	2,707	100.0

Table 193. Dependable Yield, Weiser River near Weiser, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	427	42.5
2	1930-31	426	42.4
3	1929-31	470	46.8
4	1929-32	630	62.7
5	1930-34	673	67.0
6	1929-34	653	65.0
7	1929-35	658	65.5
8	1930-37	684	68.1
9	1929-37	669	66.6
10	1929-38	765	76.2
30	1929-58	1,004	100.0

Table 194. Dependable Yield, Snake River at Weiser, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	9,697	64.3
2	1930-31	10,372	68.8
3	1933-35	10,757	71.4
4	1931-34	10,974	72.8
5	1931-35	10,857	72.0
6	1930-35	10,889	72.2
7	1931-37	11,056	73.3
8	1930-37	11,056	73.3
9	1929-37	11,185	74.2
10	1929-38	11,622	77.1
30	1929-58	15,074	100.0

Table 195. Dependable Yield, Burnt River near Hereford, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1934	34	41.5
2	1934-35	38	46.3
3	1934-36	45	54.9
4	1934-37	44	53.6
5	1933-37	49	59.8
6	1932-37	56	68.3
7	1931-37	53	64.6
8	1930-37	52	63.4
9	1929-37	52	63.4
10	1930-39	55	67.1
30	1929-58	82	100.0

Table 196. Dependable Yield, Powder River near Robinette, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1930	209	40.8
2	1930-31	220	43.0
3	1929-31	261	51.0
4	1934-37	275	53.7
5	1933-37	322	62.9
6	1930-35	332	64.8
7	1929-35	334	65.2
8	1930-37	323	63.1
9	1929-37	326	63.7
10	1929-38	357	69.7
30	1929-58	512	100.0

Table 197. Dependable Yield, Snake River below Pine Creek at Oxbow, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1935	11,124	68.1
2	1934-35	11,222	68.7
3	1933-35	11,950	73.1
4	1932-35	12,378	75.8
5	1931-35	12,140	74.3
6	1930-35	12,054	73.8
7	1929-35	12,306	75.3
8	1930-37	12,324	75.4
9	1929-37	12,490	76.4
10	1930-39	13,031	79.8
30	1929-58	16,338	100.0

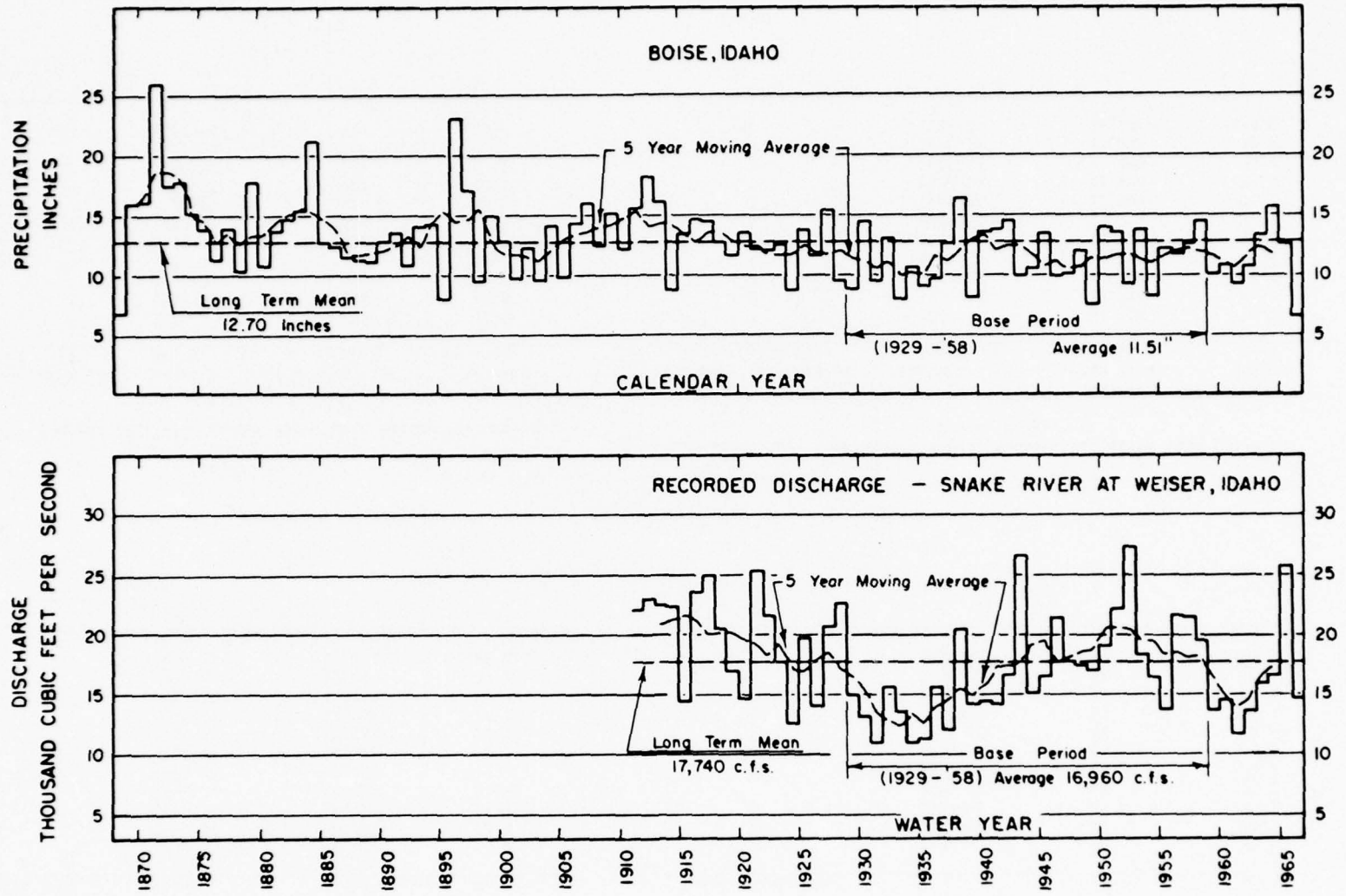


Figure 350 Long-term variation in precipitation and streamflow.

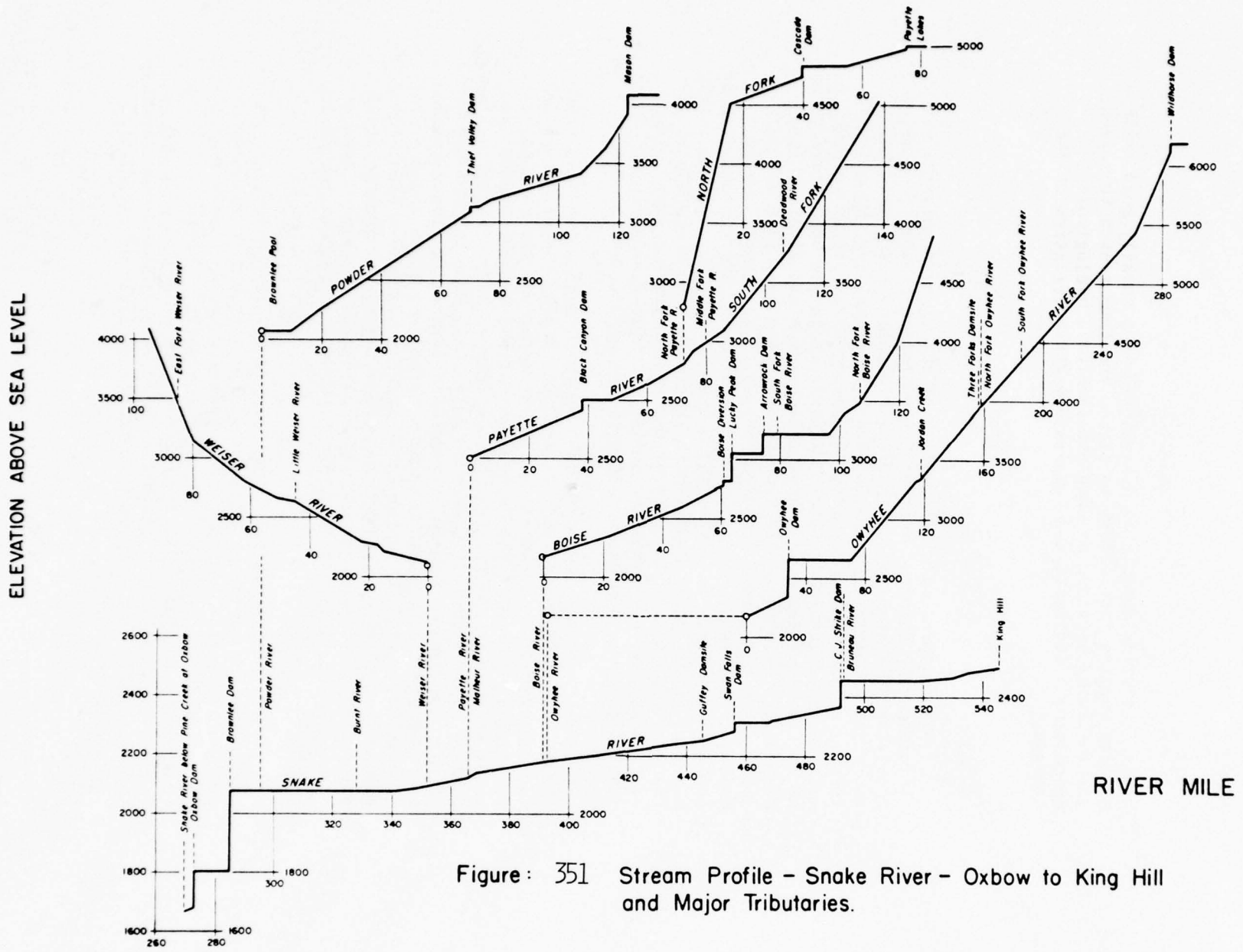


Figure: 351 Stream Profile – Snake River – Oxbow to King Hill and Major Tributaries.

Quality

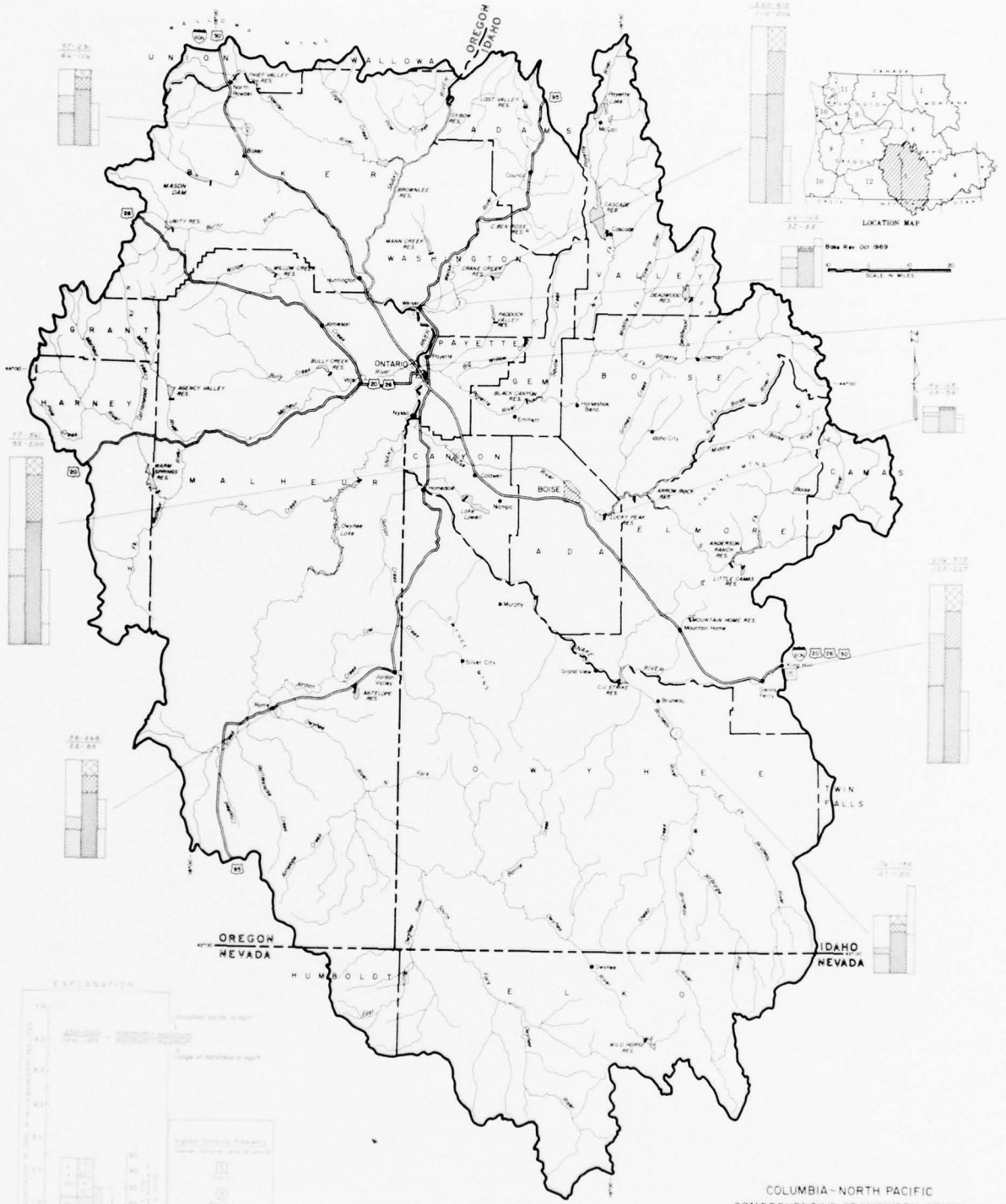
The water quality of Subregion 5 is generally good, with quality varying from stream to stream and from season to season. The following sections discuss the chemical, biological-biochemical, sediment, and temperature characteristics of the streams.

Chemical

The natural chemical quality of the streams reflects the difference in climate. Most of the subregion is arid to semiarid, receiving less than 20 inches of precipitation per year. The northeastern part of the basin, however, comprising the upper reaches of the Boise, Payette, and Weiser River Basins receives an average of 40 inches or more. Streamflows in the headwaters areas of the Boise, Payette, and Weiser Rivers are all dilute calcium magnesium bicarbonate type waters containing less than 100 mg/l (milligrams per liter) dissolved solids. The Bruneau, Owyhee, Malheur, and Powder Rivers, on the other hand, are typical of most semiarid tributary basins of the Snake River. They contain fairly dilute (100-200 mg/l) bicarbonate type waters in their upper reaches. The amounts of calcium and sodium present vary, with calcium usually predominating during the high-flow periods. During most of the year, however, sodium is the predominant cation.

Most of the streams in this basin show dramatic downstream changes in mineral quality. In some instances, the dissolved solids concentration increases tenfold or more; and the chemical composition is altered. The Owyhee, Boise, and Malheur Rivers are those which show the greatest change (figure 352). Samples collected monthly (from August 1960 through July 1961) from the Malheur River at Ontario, Oregon, had an average dissolved solids concentration of 1,040 mg/l. The maximum value reported was 1,290 and the minimum was 719 mg/l. The water at this site is a sodium bicarbonate-sodium sulfate type, with sodium accounting for an average of 62 percent of the dissolved cations. Sulfate is the predominant anion during the irrigation season, but bicarbonate predominates during the winter.

There is undoubtedly some natural downstream increase in mineralization of the rivers as they flow through this semiarid area, but the effect of man's use probably has an equal or greater effect on the chemical character of the water. Though this increase in mineralization is not actually enough to preclude reuse of the water for irrigation, much of this water would require softening and other treatment to meet municipal, domestic, and industrial standards.



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

CHEMICAL COMPOSITION OF WATER

CENTRAL SNAKE SUBREGION 5

1968

FIGURE 352

The waters of the Bruneau River and some of its tributaries contain fluoride concentrations in excess of the limits set for drinking waters by the Public Health Service. The average fluoride concentration of six samples collected from Little Valley Creek near Bruneau was 9.5 mg/l. Ten samples collected from the Bruneau River at Hot Spring during the 1959 water year averaged 2.7 mg/l.

Biological-Biochemical

Streams within the subregion are generally well aerated, and dissolved oxygen concentrations are near saturation. A persistent oxygen depression does occur in Brownlee Reservoir at the lower end of the subregion where surface dissolved oxygen concentrations are consistently 4 or 5 mg/l lower than the levels found immediately upstream. Dissolved oxygen deficiencies are suspected in downstream reaches of the Boise River where, seasonally, waste discharges may constitute a significant portion of the flow. Suspended organic material resulting from food processing also has resulted in sludge deposits in the lower reaches of the Boise River and elsewhere. Bacterial quality is variable, with some areas rendered unsuitable for water contact recreation. However, a significant portion of high bacteria counts may be attributable to large animal populations, plants, and soil bacteria.

Table 198 - Dissolved Oxygen & Coliform Organisms Densities
Central Snake Subregion

Location	Dissolved Oxygen mg/l			Coliform Organisms /100 ml		
	Mean	Min	Max	Mean	Min	Max
Succor Creek at Hwy 19	10.7	9.9	11.9	1,923	230	7,000
Crooked Creek at Hwy 95	8.8	8.1	9.6	2,555	620	7,000
Owyhee R. at Hwy 95	10.7	7.5	14.0	455	130	620
Jordan Creek at Hwy 95	8.7	6.6	11.1	218	60	450
Owyhee R. at Hwy 201	9.0	8.2	9.7	4,700	2,400	7,000
Snake R. at Nyssa	11.1	5.8	13.5	9,781	60	70,000
Snake R. at Ontario	10.8	6.6	13.8	9,456	600	70,000
Malheur nr. Vale	11.4	7.2	20.0	3,225	600	24,000
Malheur nr. Ontario	10.5	7.2	18.4	2,145	230	7,000
Snake R. at Payette	10.5	5.7	13.7	7,898	230	24,000
Snake R. at Weiser	10.3	7.0	13.3	9,080	60	70,000
Powder R. nr. Baker	10.3	4.2	15.6	8,629	460	70,000

The available information shown on table 198 indicates poor bacterial quality at most stations listed, a situation which is probably not representative of the entire subregion. The downstream reaches of the Boise River have consistently been high in coliform densities, although the situation has improved in recent years. Even so, levels of 71,000 organisms/100 ml were recorded

in the winter of 1965 when flows were reduced by upstream storage dams. Higher counts have been measured in Indian Creek, a tributary of the Boise River. The chemical composition of water is shown in figure 352.

The Owyhee, Malheur, and Boise Rivers contribute to phosphate concentrations in the Snake River resulting in nutrient conditions which promote nuisance aquatic growth. As an example, analyses of samples collected since 1960 from the Malheur River near Ontario, Oregon, show that the mean total phosphate concentration is 1.2 mg/l, with a maximum of almost 5 mg/l; these levels exceed those required to stimulate algal growth.

Sediment

Measurements of suspended sediment concentration and loads were obtained in the Boise River Basin in 1939-40. Other data, mostly unpublished, were obtained between 1905 and 1961 in several other river basins. Studies of these data suggest that suspended sediment was little more than half the total load. (30) In addition, suspended sediment samples showing instantaneous concentrations as high as 20,700 mg/l were obtained during recent floods as shown on figure 353. Data on reservoir sedimentation were obtained in Elmore, Ada, Boise, Payette, and Washington Counties (Idaho) in 1951. The sediment yields shown on figure 353 indicate that production ranges between 0.02 and 1.5 acre-feet per square mile per year. (30) Only in one small area near Boise does yield exceed 0.5 acre-foot per square mile per year; most of the subregion yields between 0.1 and 0.2. (30) The predominant sources of finer sediment are sheet and rill erosion in the upland watersheds. Additional amounts of fine sediment have, in the past, been contributed by placer mining operations. Some of the coarser sand is derived from sheetwash on steep mountain slopes, particularly where the vegetation has been depleted by intensive grazing.

Water Temperature

Water temperature profiles for the main stem Snake River from King Hill to the mouth appear in the weekly and monthly reports of the Geological Survey. In the reach of the river covered by Subregion 5 (King Hill to Oxbow), data from four stations are used in constructing these profiles. Two of the stations have been reporting temperatures since 1952, but temperature data from the other two are more recent. Average conditions have not yet been adequately identified at the latter two stations; therefore, a



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERALIZED SEDIMENT YIELD

CENTRAL SNAKE SUBREGION 5

1969

FIGURE 353

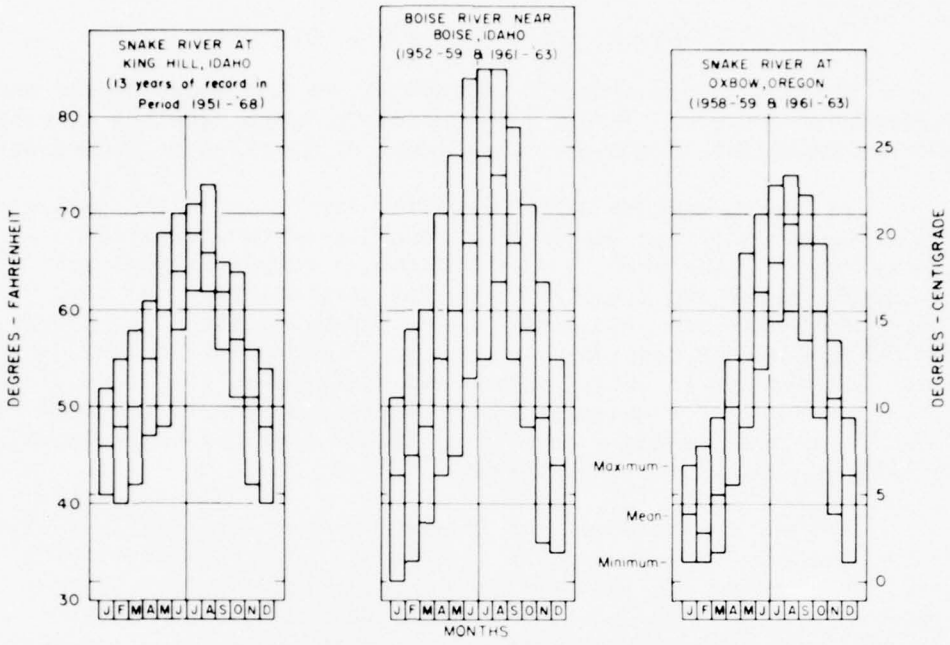


Figure 354 Monthly water temperatures for selected stations

temperature profile has not been constructed for this report. Instead maximum, minimum, and mean monthly water temperatures are shown on figure 354 for the Snake River at King Hill and at Oxbow Dam. Also shown are data for the Boise River at Notus, where records have been taken for several years.

GROUND WATER

Five aquifer units furnish important supplies of ground water at various places in Subregion 5. Two of these are composed of sedimentary deposits and three are chiefly of volcanic materials. All five are Miocene to Holocene in age.

Water quality generally ranges from fair to excellent; the dissolved solids content commonly is less than 500 mg/l. However, at some places the older volcanic rock aquifers yield water with higher concentrations of dissolved solids, sometimes with excessive sodium, occasionally with excessive fluoride.

Reports of 12 areal investigations describe aquifers and ground-water conditions in parts of Subregion 5. (10, 23, 28, 41, 68, 86, 94, 99, 124, 152, 161, 180)

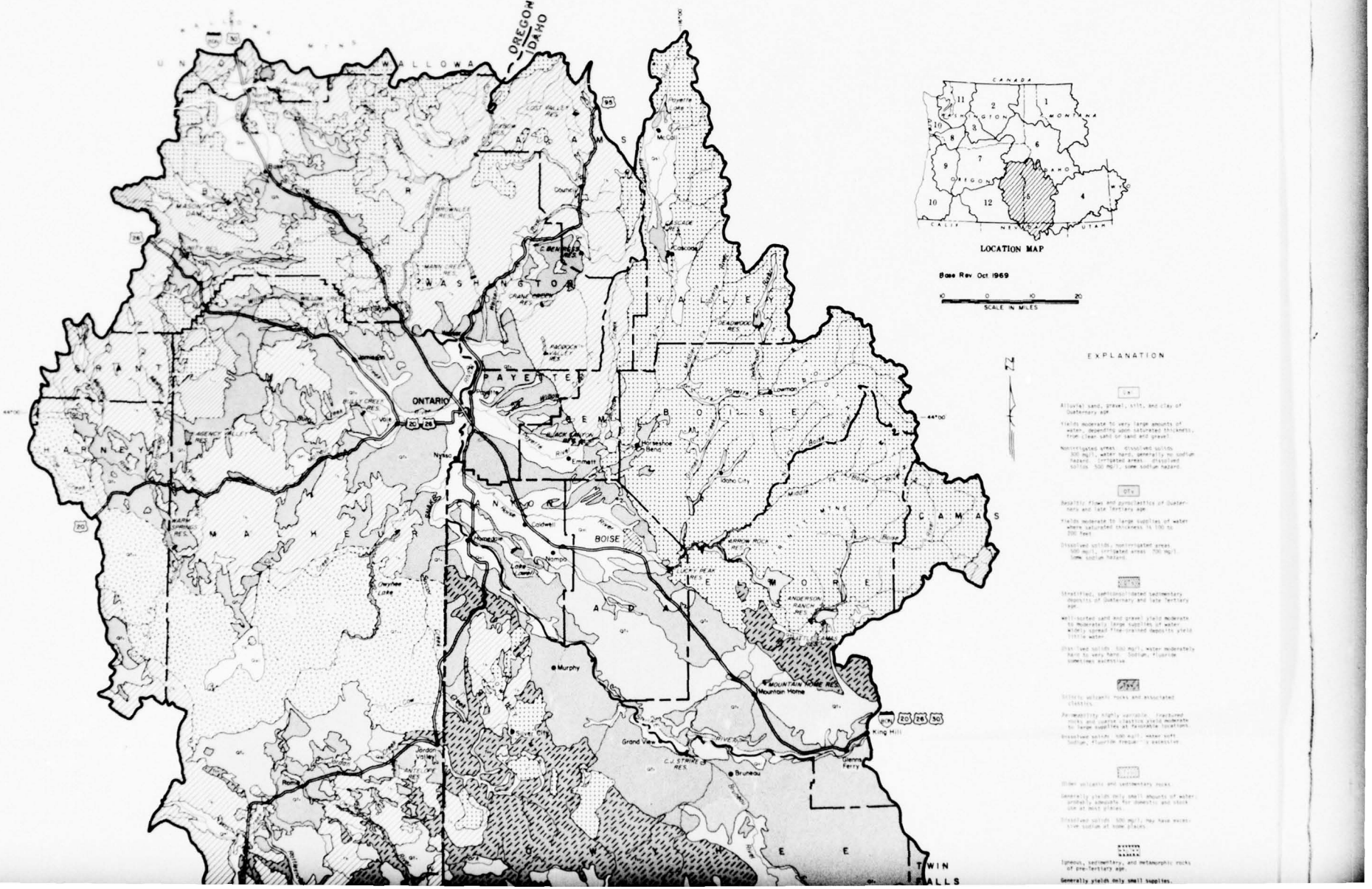
Aquifer Units and Their Hydrologic Characteristics

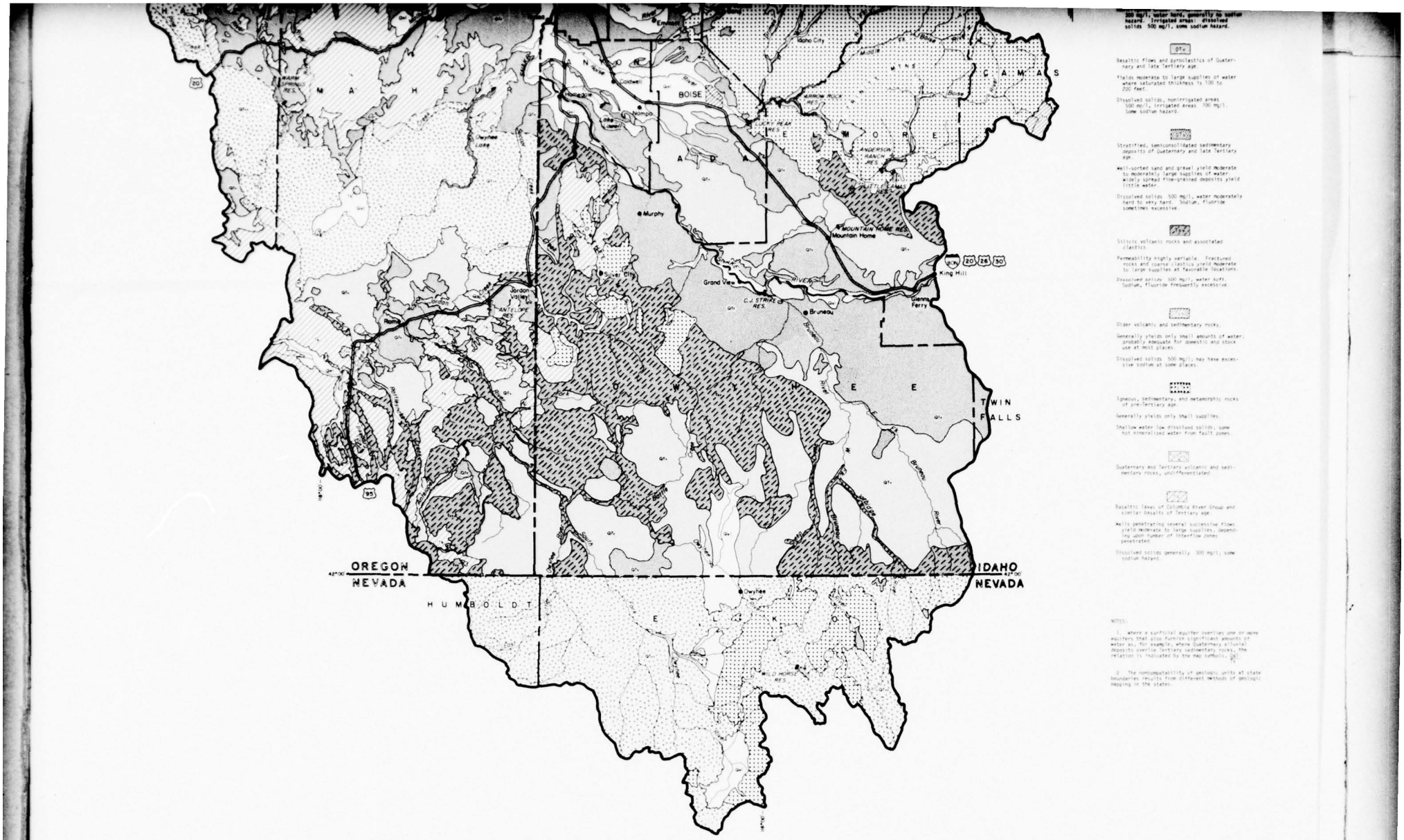
Eight aquifer units are delineated and are shown on the map, figure 355. Five of these yield moderately large supplies at places and are important in the development and utilization of ground water.

In Idaho, aquifer unit boundaries are based on the geologic map of Idaho (133); in Nevada, the unpublished map compiled by Montgomery (79) was used; and, in Oregon, a number of geologic maps of varying scale and detail (7 and 185) were utilized in compiling the aquifer unit map. Inconsistencies appear on the aquifer unit map because of the considerable number of sources of information, large differences in detail shown, and differences in interpretation of the geology. For example, lower Pliocene basalt is included with the younger volcanic rock (QTv) in one area but is included as Tertiary basalt (Tb) in another.

The alluvial deposits of Quaternary age (Qal) include stream alluvium underlying the present flood plain; alluvium underlying benches and terraces; outwash and other glacial deposits, lacustrine silt, clay, and fine sand; and windblown sand deposits. Locally, some alluvial deposits are interbedded with the younger basaltic lavas (QTv) and are included with that aquifer unit. Porous and permeable coarse sand and gravel deposits are extensive along the Snake River Valley and in the Boise, Payette, Weiser, Malheur, and Baker Valleys. They are thick enough in most of the larger valleys to yield moderately large to large quantities of ground water. Yields from 50 to 150 feet of the coarser material commonly are 500 to 2,500 gpm.

The volcanic rocks of late Tertiary and Quaternary age (QTv) include basalts in the Snake River and Idaho groups. (72) These lavas and the interbedded pyroclastics and alluvial deposits constitute one of the most prolific aquifer units in the subregion. The lava flows usually range in thickness from about 10 to 50 feet, probably averaging 20 to 25 feet. The central part of an individual flow generally has low permeability; however, the upper surfaces of most flows are irregular, and sometimes very rough and blocky. The permeable zone resulting where subsequent flows did not completely fill these openings makes these rock sequences good aquifers. Scoria, coarse cinders, or gravel are interbedded in the lavas at places and also are good aquifers. Silt or clay interbeds, however, greatly reduce the permeability of the interflow zones. Large yields are obtained from the basalt south of Nampa and Boise, between Boise and Mountain Home, and in the vicinity of Mountain Home. Where the saturated thickness is 100 to 200 feet, wells commonly yield 1,000 to 3,000 gpm with a few feet of drawdown.


OREGON
IDAHO
WALLOWA
WASHINGTON
ADAMS
PAYETTE
ONTARIO
BOISE
VALLEY
ELMORE
CAMAS
MALHEUR
HARNEY
GRANT
McCall
Council
Weiser
Emmett
Idaho City
Nyssa
Vale
Ontario
Nampa
Murphy
Mountain Home
King Hill
Grand View
Bruneau
Glenns Ferry
Jordan Valley
TWIN FALLS
LOCATION MAP
Base Rev. Oct 1969
SCALE IN MILES
EXPLANATION



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

AQUIFER UNITS

CENTRAL SNAKE SUBREGION 5

1968

FIGURE 355

The sedimentary deposits of Quaternary and Tertiary age (QTs) include sediments of the Snake River and Idaho groups, the Payette Formation, and similar strata. These deposits consist of thick sections of silt, tuffaceous siltstone, sandstone, clay, and fine sand, with thinner lenses of medium to coarse sand and gravel that are moderately permeable. Lava flows are interbedded in the deposits at some places. At many places the unit furnishes 100 to 1,000 gpm to wells a few hundred feet deep. Specific capacities generally range from 5 to 60 gpm per foot of drawdown. In general, the younger strata in the Snake River and Idaho groups and equivalent strata of middle Pliocene to Pleistocene age are considerably better aquifers than the Payette Formation and equivalents of Miocene and lower Pliocene age. However, the maps available do not permit separating the two groups. Irrigation supplies are obtained from this unit in the Dry Lake area south of Nampa and in the Bruneau-Grand View area.

The silicic volcanic rocks (Tsv) include latite and rhyolite flows, dacite, welded tuff, stratified tuff, tuffaceous silt, and some conglomerate beds. The porosity and permeability are highly variable, and yields of individual wells range widely. Joints and fault zones in dense rocks and coarser-grained clastic and pyroclastic rocks probably would yield moderate to large supplies of water at favorable locations. The massive unbroken rocks yield little water. No data are available regarding yields of wells in this unit in Oregon; but in the Bruneau-Grand View area of Idaho, large yields are obtained from deep wells drilled for irrigation supply. (68-161) Small to moderate yields generally are available for stock and domestic use.

Basaltic lavas (Tb), including the Columbia River Group and similar rocks of Miocene to lower Pliocene age, form wide upland segments and are important aquifers, particularly in Oregon. The basalt is light to dark gray; jointing is irregular to columnar, but locally is platy. The flows generally are 25 to 100 feet thick. Interbeds of tuff, ash, and sand and gravel are common. Individual flows generally have low permeability, but some of the zones at and adjacent to the contacts of successive flows are moderately permeable. Where several interflow zones are penetrated, moderate to moderately large yields are usually obtained. Important supplies are obtained from this unit at several places including the upper Weiser Valley, Cow Valley, and in the Malheur Basin.

A large area in Oregon and most of Nevada have been mapped in only a very general way. These areas have been shown on various maps as being underlain by Miocene or younger volcanic and sedimentary rocks. In this report they are shown as Quaternary and Tertiary volcanic and sedimentary rocks (QTvs) and are equivalent to other aquifer units (QTv, QTs, Tsv, and Tb) that are shown separately on other parts of the map.

The older volcanic and sedimentary unit (Tvs) includes a variety of rocks, chiefly of volcanic origin, ranging in age from Eocene to Miocene(?). Two areas of the Clarno Formation north of the Malheur River (7) and a small area of Challis volcanics at the head of the South Fork Boise River are included in the unit. Both the Clarno Formation and the Challis volcanics include rhyolitic to basaltic flows, welded tuff, breccia, and tuffaceous sedimentary rocks. The little information available suggests that the rocks have low porosity and permeability and generally yield only small supplies for domestic and stock use. A few wells have moderate yields from coarse-grained or greatly fractured rocks.

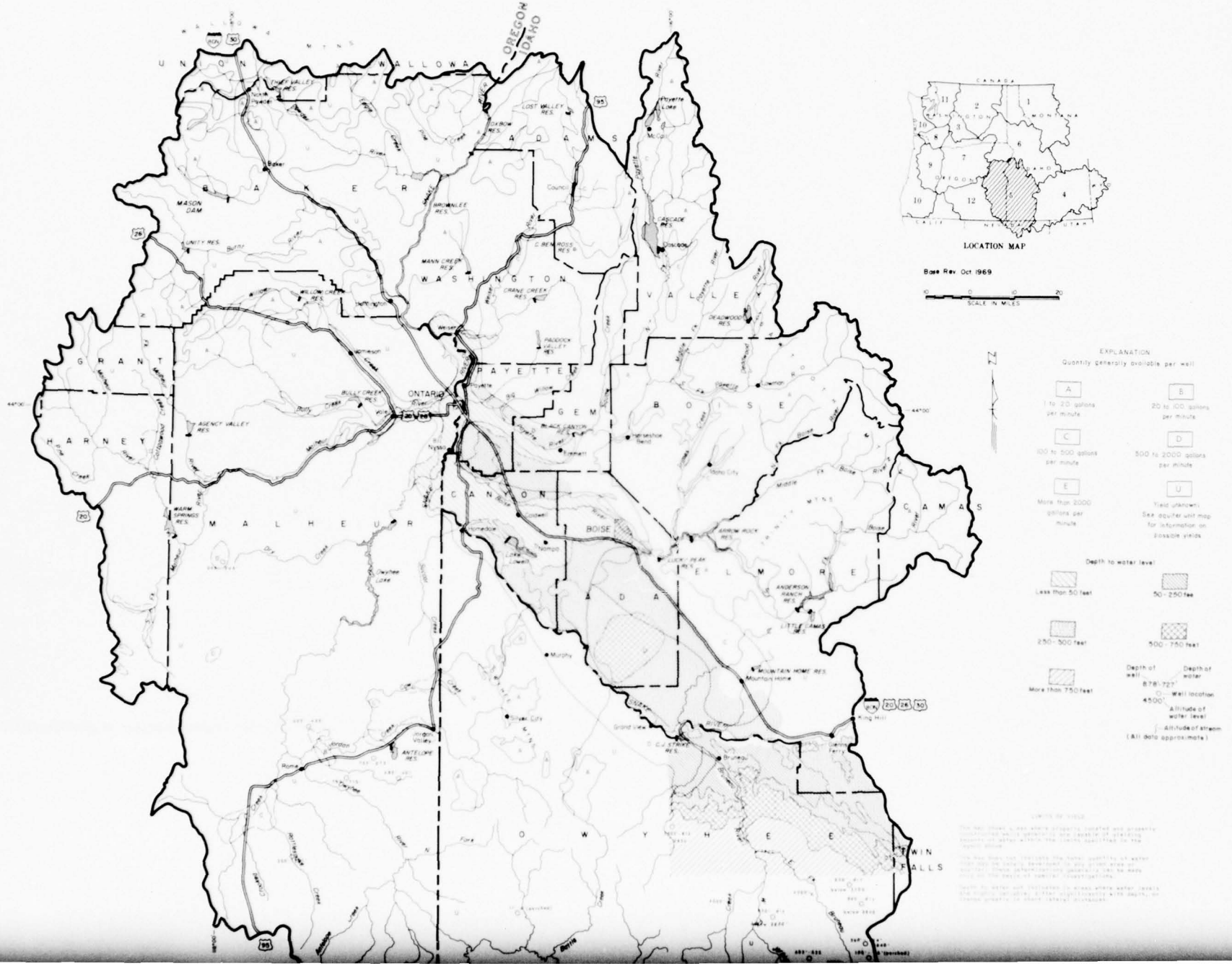
All rocks older than Tertiary are grouped into the pre-Tertiary aquifer unit (pT). Included are granite and other intrusive igneous rocks; gneiss, schist, greenstone, and similar metamorphic rocks; and stratified, consolidated sedimentary rocks such as shale, limestone, sandstone, and conglomerate. Generally, the porosity and permeability of these rocks are very low; and most wells have only small yields, although rarely a well may encounter faults, joints, or cavities in limestone and have a moderate to large yield. The pre-Tertiary rocks have a moderately deep zone of weathering that is considerably more porous and permeable than the underlying rock. The weathered zone supports many small springs, and shallow dug wells in it generally yield adequate supplies for domestic use. The chief importance of the aquifer unit is in supplying a large volume of fairly short-term storage that maintains the base flow of streams draining the mountainous areas.

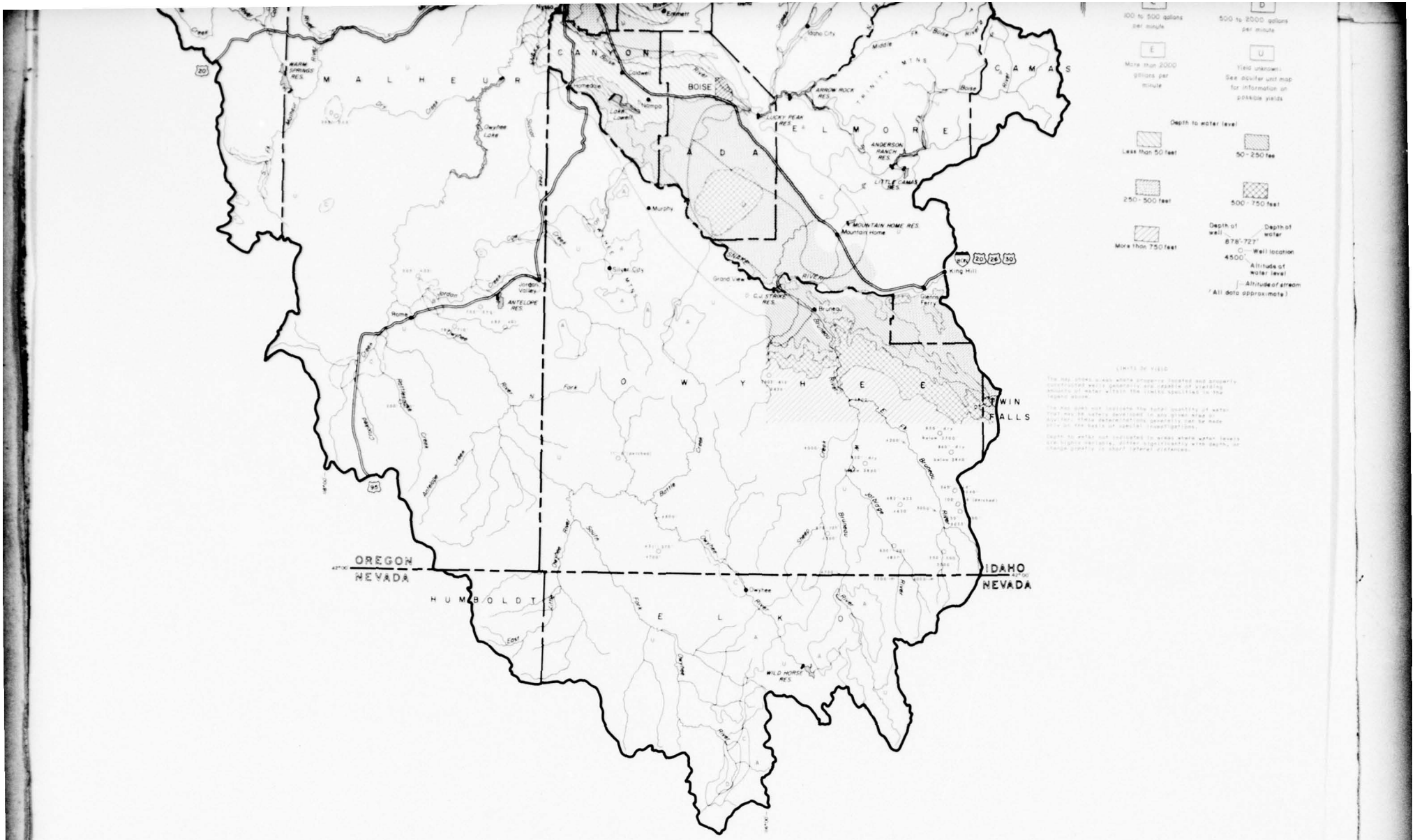
Summary descriptions of the aquifer units, their general hydrologic characteristics, and the general quality of water yielded by them are given in table 199. The general availability of ground water is shown in figure 356; large areas are marked as "unknown" because the geology is little known and few well records are available. For maximum usefulness, the maps showing aquifer units and the general availability of ground water, figures 355 and 356, should be used together.

Water in Storage

A rough estimate of the quantity of water in storage in each aquifer unit in a specified depth interval below the water table is presented in table 200.

Specific yield values were assigned as described in the Regional Summary and in the section on Subregion 4.


OREGON
IDAHO
UNION
WALLOWA
BAKER
ADAMS
WASHINGTON
PAYETTE
GEM
BOISE
GRANT
HARNEY
MALHEUR
CANYON
ADA
ELMORE
CAMAS
OWYHEE
TWIN FALLS
ONTARIO
BOISE
Baker
MASON DAM
UNITY RES.
BROWNLEE RES.
OXBOW RES.
LOST VALLEY RES.
MANN CREEK RES.
CRANE CREEK RES.
C. BENGROSS RES.
COUNCIL
CASCADE
DONNELLY
McCALL
DEADWOOD RES.
PAYETTE
BULLY CREEK RES.
AGENCY VALLEY RES.
WARM SPRINGS RES.
ARROW ROCK RES.
LUCKY PEAK RES.
ANDERSON RANCH RES.
LITTLE AMES
MOUNTAIN HOME RES
Mountain Home
C.J. STRIKE RES.
ANTELOPE RES.
Murphy
Nyssa
Jordan Valley
Rome
Grand View
Bruneau
King Hill
Burley
Twin Falls
Hailey
Ketchum
Sun Valley
Idaho City
Emmett
Weiser
Payette
Ontario
Vale
Nampa
Caldwell
Meridian
Boise
Parma
Homedale
Marsing
Jordan
Owyhee
Silver City
Mountain
Fork
Snake
Malheur
Agency Valley
Warm Springs
Bully Creek
Unity
Burnt
Powder
Grande Ronde
Wallowa
Imnaha
Pine Valley
Juntura
Crane
Harney
Alvord
Steens
Owyhee
Jarbidge
Rogerson
Contact
Salmon
Challis
Mackay
Arco
Carey
Shoshone
Gooding
Hagerman
Wendell
Jerome
Rupert
Heyburn
Malad
Oakley
Albion
Burley
Declo
Raft River
Elko
Wells
Jackpot
Mountain
Home
Glenns Ferry
Mountain Home
Boise
Nampa
Caldwell
Ontario
Vale
Payette
Weiser
Emmett
Idaho City
Ketchum
Sun Valley
Hailey
Twin Falls
Burley
Rupert
Heyburn
Malad
Oakley
Albion



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERAL AVAILABILITY OF GROUND WATER AND DEPTH TO WATER LEVEL

CENTRAL SNAKE SUBREGION 5

FIGURE 356

Table 199 - Description of Aquifer Units and Their Hydrologic Characteristics, Subregion 5

Map Symbol and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
Qal: Chiefly alluvial deposits along Snake River and its larger tributaries. Widespread in Snake River, Boise, Payette, Weiser, and Baker Valleys. Includes lacustrine, eolian, and glacial deposits. Pleistocene to Holocene in age.	Sand, gravel, and silt deposited as stream channel and over-bank deposits on floodplains; and as deltas. Locally includes clay, silt, and sand deposited in lakes. Deposits are lenticular, poorly to moderately well sorted; unconsolidated to lightly cemented.	Coarser alluvium yields moderate to large supplies of water to wells. Specific capacities commonly range from 25 to 100 gpm per foot. Aquifer recharged by irrigation in most valleys, locally in some high level small valleys by seepage from streams.	Dissolved solids generally less than 300 mg/l except where percolating irrigation water has increased mineral content. Water soft to very hard.
QTv: Basaltic volcanic rocks of the Snake River and Idaho Groups and similar lavas in eastern Oreg. Chiefly extruded as domes, cones, and intercanyon flows. Middle Pliocene to Holocene in age.	Olivine basalt, light to dark gray, dense to vesicular, frequently open textured; irregular to columnar jointing. Includes beds of basaltic cinders, scoria, and stratified interbeds of clastics and pyroclastics.	Individual flow units have low internal permeability; water moves chiefly through rubbly interflow zones. Scoria and cinders add to porosity, permeability of the zones. Specific capacities of 500-1,000 gpm per foot of drawdown are common.	Dissolved solids less than 500 mg/l except where irrigation water has increased mineral content. Water soft to hard.
QTs: Deposits of lacustrine and fluviatile origin; includes sediments of Idaho Group, Payette Fm., and similar unnamed deposits in Oreg. Miocene to Middle Pleistocene in age.	Unconsolidated to moderately consolidated silt, clay, diatomite, sand, gravel, ash, tuffaceous siltstone and sandstone. In places includes basalt or andesite flows. Thin to thick bedded, lenticular; crossbedding common in sandy units.	Coarse-grained phases yield moderate to large quantities of water. Wells in clean, well sorted sand and gravel will generally have moderate to large yields. Water usually under some artesian pressure. Unit is important aquifer in Snake and Boise Valleys.	Dissolved solids less than 500 mg/l; water generally moderately hard to hard. Percent sodium ranges from low to high.
Tb: Basaltic rocks including basalt of the Columbia River Group, Strawberry Volcanics, and similar unnamed units of Middle Miocene to early Pliocene in age.	Fissure basalt, light to dark gray, dense; irregular to columnar jointing, locally platy. Many thin interbeds of tuff, ash, and diatomite; some sand and gravel.	Individual flows are dense except in upper part, yield little water. Water-bearing zones are at and immediately below contacts of successive flows. Wells yield moderate to large supplies depending on number of permeable interflow zones penetrated.	Dissolved solids generally less than 300 mg/l, silica relatively high. Water soft to hard. Boron very low.
Tsv: Silicic volcanic rocks and associated clastics, chiefly silicic, and of volcanic origin. Includes 'Tsv' of State of Idaho map, and similar rocks of late Miocene to early Pliocene age in Oregon.	Silicic latite, chiefly thick layers of devitrified welded tuff, includes some bedded vitric tuff; tuffaceous sedimentary rocks, and rhyolitic flows. Contains some conglomerate beds.	Porosity and permeability highly variable. Fractures and coarser-grained clastics probably yield moderate to large supplies of water at favorable locations. Massive unbroken rock yields little water. Important aquifer in Bruneau-Grand View area of Idaho.	Information available in Bruneau-Grand View area only. Dissolved solids less than 500 mg/l; water soft; high silica and sodium. Water generally warm to hot.
Tvs: Older volcanic and sedimentary rocks include Clarno Fm. of Eocene age, Challis Volcanics of Eocene to Miocene age.	Flow rocks of basaltic, rhyolitic, and intermediate composition, breccia, tuff and volcanic conglomerate, some tuffaceous silt beds.	Little information available but generally has low porosity and permeability, commonly yields small quantities of water. Probably will yield supplies adequate for domestic and stock use at most places.	Few data available. Dissolved solids generally less than 500 mg/l; may have high sodium content at some places.
pT: Rock units of pre-Tertiary age. Includes intrusive igneous rocks, sedimentary strata, volcanic rocks, and metamorphosed sediments and volcanics.	Granitic rocks of Idaho Batholith, Wallowa Mts.; diorite, gabbro and other intrusives; schist, slate, greenstone, argillite, quartzite; tuffaceous and calcareous sedimentary rocks; pyroclastic and volcanic flows.	Porosity low. Joints, faults, and other secondary openings serve as limited avenues of water movement. Little information available on well yields but probably are small. Deep weathered zone together with talus and colluvium forms important shallow reservoir that maintains base flow of streams.	Shallow water low in dissolved solids, soft to moderately hard, chiefly calcium bicarbonate type. Some highly mineralized hot water comes up from depth along fault planes.

Table 200 - Storage, Recharge, and Discharge of Ground Water in Aquifer Units in Subregion 5

Aquifer Unit	Area		Storage			Annual Natural Recharge and Discharge	
	Sq. Mi.	Acres (1000's)	Specific Yield (percent)	Depth Used (ft)	Water (1000's ac-ft)	Inches Over Area	(1000's ac-ft)
Qal	3,000	1,920	20	50	19,200	12	1,920
QTv	4,680	3,000	5	100	15,000	2	500
QTs	6,420	4,100	10	100	41,000	1	340
Tsv	3,650	2,300	2	100	4,600	1	200
Tb	6,260	4,000	1	100	4,000	1	330
QTvs 1/	4,670	3,000	5	100	15,000	1	250
Tvs	460	290	2	50	290	1	25
pT	7,420	4,750	1	50	2,400	3	1,200
TOTAL (rounded)	36,600	23,360			100,000		5,000

1/ Includes volcanic and sedimentary rocks of Quaternary and late Tertiary age corresponding to the younger volcanic rocks (QTv), younger sedimentary rocks (QTs), silicic volcanic rocks (Tsv) and Tertiary basalt (Tb).

Because the volcanic and sedimentary rocks of Quaternary and Tertiary age (QTv, QTs, Tsv, and Tb) occur largely in water-short areas, a depth interval of 100 feet was used for these units. A depth of 50 feet was used for the alluvial deposits (Qal), the older volcanic and sedimentary rocks (Tvs), and the pre-Tertiary rocks (pT).

About 100 million acre-feet of water are stored in the specified depth interval in Subregion 5 (table 200). More than 30 percent of this water is in the two most important aquifer units, the alluvial deposits (Qal) and the younger volcanic rocks (QTv). Large volumes of water also are contained in the Quaternary and Tertiary sediments (QTs) and the Tertiary volcanic rocks (QTvs, Tb). However, in the Owyhee area in Idaho, Nevada, and Oregon the water table may be many hundreds of feet below land surface, thus making the stored water more expensive to recover.

Natural Recharge and Discharge

The older Tertiary volcanic and sedimentary rocks (Tvs) and the pre-Tertiary rocks (pT) are largely confined to mountainous areas. Recharge to these units is almost entirely from precipitation and snowmelt. There is little recharge during the summer months (July-September). Discharge from these units is into the many small streams draining them and at some places is directly into the larger streams. However, part of the discharge from these rocks is by lateral inflow to the alluvial deposits and younger volcanic rocks underlying the valleys. Tertiary basalt (Tb) and Tertiary and Quaternary sedimentary rocks (QTs) underlie extensive plateau and upland areas north of the Snake River Valley in Idaho and the Malheur Valley in Oregon. Southward, the upland and plateau areas are partly underlain by these two aquifer units, but in larger part by the Tertiary silicic volcanic rocks (Tsv) and Tertiary and Quaternary volcanic rocks (QTv). The aquifers of all these upland and plateau areas are recharged chiefly by direct precipitation and snowmelt, and to some extent by influent seepage from streams draining the older, less permeable rocks of the mountainous areas. Generally, only the major streams receive effluent seepage from the Tertiary basalt (Tb), silicic volcanic rocks (Tsv), younger sedimentary deposits (QTs), and younger volcanic rocks (QTv) underlying the upland areas; the smaller streams are above the regional water table and are intermittent and influent. One or more of the four above-mentioned aquifer units underlies each of the major valleys or basins, and ground water moves from upland areas through these aquifer units into the valleys and basins where it discharges into streams, or leaks upward under artesian pressure to recharge overlying shallower aquifers. Hydrographs of observation wells are shown in figure 357.

Recharge in the valleys and basins is partly from lateral ground-water inflow and precipitation, but is chiefly from irrigation. Discharge is into drains, small streams, and major trunk streams. Some of this water is rediverted for irrigation.

A rough estimate of annual recharge and discharge of aquifer units is given in table 200. Total gross annual recharge and discharge is estimated to be about 5 million acre-feet. The quantity of ground water recycled is not known, but is estimated at about 1 million acre-feet, leaving a net annual recharge and discharge of 4 million acre-feet. The Boise Valley above Notus, an area of 234,000 acres, was estimated by Nace (94-48, table 16) to have an annual ground-water supply of 951,000 acre-feet. That part of the Boise Valley is less than 20 percent of the total area of comparable valleys in Subregion 5, so the estimate of 4 million acre-feet net annual recharge and discharge may be low.

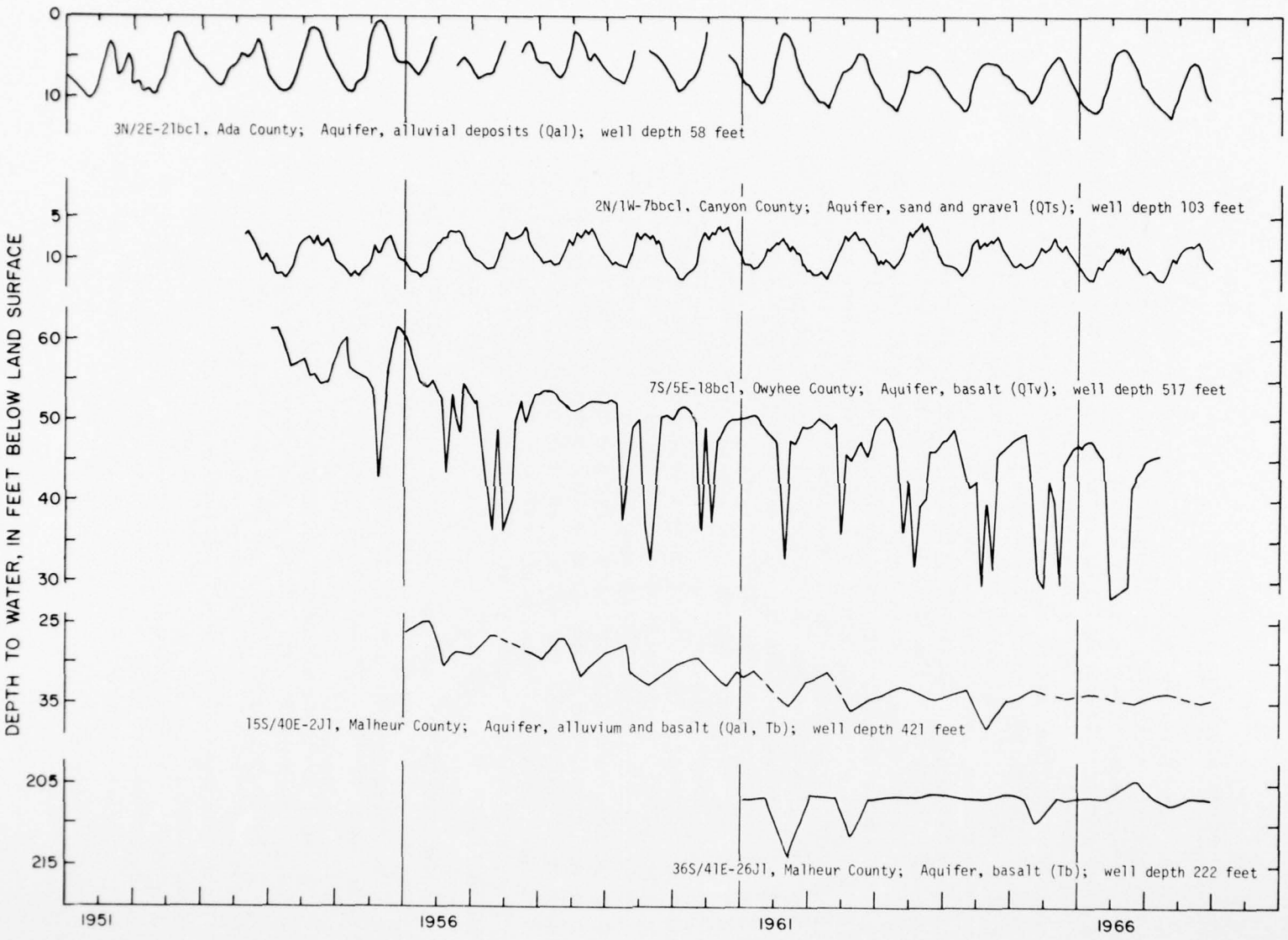


Figure 357 Hydrographs of selected wells in subregion 5

Annual Ground-Water Withdrawal

Annual ground-water withdrawal based on 1967 data and projected to 1970 (table 201) is estimated to be about 630,000 acre-feet. A little more than 500,000 acre-feet a year is withdrawn for irrigation, chiefly from the alluvial deposits (Qal) and the younger volcanic rocks (QTv); but considerable quantities also are withdrawn from the other volcanic and sedimentary rock aquifers (QTs, Tsv, and Tb).

Chemical Quality of Water

Total dissolved solids generally are less than 300 mg/l for water in the alluvial deposits and less than 500 mg/l in water from the younger volcanic rocks. The water is chiefly of the calcium magnesium bicarbonate type and is moderately hard to very hard. Sodium concentrations are high in some samples and the water is soft. Boron and fluoride generally are less than 0.5 mg/l and 1 mg/l, respectively. Apparently there is some deterioration of water quality, including an increase in sodium percentage because of recirculation of water used for irrigation. A general deterioration in water quality in a downstream direction was reported for the Boise Valley. (94-72)

Water in the sedimentary deposits (QTs) generally has dissolved solids concentrations of less than 500 mg/l and the water is soft to hard. The percent sodium ranges from low to high; fluoride is excessive at some places.

Water from the Tertiary basalt (Tb) usually has dissolved solids concentrations of less than 300 mg/l. It is of the calcium bicarbonate type and is moderately hard to hard, but at a few places sodium is high and the water is soft. Silica ranges from 40 to 60 mg/l; boron is very low.

Water from the silicic volcanic rocks (Tsv) in the Bruneau-Grand View area has dissolved solids concentrations of less than 500 mg/l, is soft, and generally has high silica and sodium concentrations. Fluoride frequently is excessive, but boron usually is less than 1 mg/l. Water from many wells is warm to hot.

Little information is available regarding the chemical character of water in the older volcanic and sedimentary rocks (Tvs). The concentration of dissolved solids is mostly less than 500 mg/l. Sodium concentrations are high at some places. Most of the water from shallow depths in the pre-Tertiary rock unit (pT) is low in dissolved solids. It is chiefly of the calcium bicarbonate type and soft to moderately hard. Water from limestone generally is hard to very hard.

Table 201 - Estimated Ground-Water Withdrawal and Consumptive Use, Subregion 5, 1970

	Ac-ft per year; all quantities in thousands			
	Idaho	Oregon	Nevada	Total
Irrigation				
Acres irrigated	150.0	7.0	0.5	157.0
Withdrawal	500.0	24.0	1.0	525.0
Consumptive use	250.0	12.0	-	260.0
Industrial[1/]				
Withdrawal	37.0	4.3	-	41.3
Consumptive use[2/]	1.8	.2	-	2.0
Public Supplies				
Persons served	153.0	21.0	-	174.0
Withdrawal	42.0	5.3	-	47.0
Consumptive use[3/]	8.4	1.1	-	10.0
Rural-Domestic				
Persons served	102.0	13.0	1.0	116.0
Withdrawal[4/]	10.4	1.4	.1	12.9
Consumptive use[5/]	5.2	.7	-	5.9
Stock				
Withdrawal and consumptive use[6/]	3.06	1.20	.17	4.43
TOTAL WITHDRAWAL (rounded)				630.0
TOTAL CONSUMPTIVE USE (rounded)				280.0

1/ Self-supplied industrial.
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

There are more thermal springs listed for Idaho by Waring (196-26, figure 4) than for any other state, and probably more than half are in Subregion 5. Large numbers of hot springs issue from granite of the pre-Tertiary rock unit (pT), apparently along faults. Hot springs in the Bruneau and Boise-Mountain Home areas issue from sedimentary rocks (QTs) or volcanic rocks (Tsv, QTv); but they probably are of deep origin, rising along fault planes. A number of artesian wells yield similar waters in those areas. According to Walker (180-81), sodium bicarbonate water is the most common thermal water. A second type is sodium chloride water. Generally, the concentration of dissolved solids is less than 1,000 mg/l; but concentrations ranging up to 9,200 mg/l have been noted. The maximum temperature listed by Waring is 190°F.

Present Use and Future Availability

Estimates of ground-water withdrawal and consumptive use are given in table 201. Total withdrawal for all uses is estimated to be about 630,000 acre-feet as of 1970. Consumptive use is estimated to be about 280,000 acre-feet. Average annual net withdrawal of ground water probably is on the order of 400,000 to 500,000 acre-feet.

Ground-water withdrawals in Subregion 5 are concentrated in the alluvial basins of the Snake River and its major tributaries. Areas of major development include the Snake River Valley between Bruneau and Weiser, Boise Valley west of Boise, Payette Valley west of Emmett, and Malheur Valley downstream from Harper.

In the Bruneau-Grand View area of the Snake River Valley, flowing and pumped wells obtain water from four aquifer units (QTv, QTs, Tvs, and Qal). Ground-water discharge was estimated to be about 22,500 acre-feet in 1954. (68-174) There have been more than a dozen wells drilled since then, and withdrawals now may be on the order of 35,000 to 40,000 acre-feet. One observation well showed a decline of 12 feet between 1953 and 1966, a little less than 1 foot a year; however, the rate of decline was considerably less during the last half of the period. (12-36, figure 29)

A large number of flowing and pumped wells withdraw water from the alluvial deposits (Qal), sedimentary rocks (QTs), and the younger volcanic rocks (QTv) in the Boise Valley west of Boise. The yearly gross withdrawal was estimated to be about 150,000 acre-feet in the period 1953-55. (94-47) Many additional wells have been drilled in the Boise Valley since 1954, and there was considerable development of ground water for irrigation in the Dry Lake area of southern Canyon County in the 1950's. More recently (1964-67) ground-water pumpage from the younger volcanic rocks (QTv) on the plateau south of Boise has expanded rapidly.

Many wells obtain water from the alluvial deposits (Qal) in the lower Malheur Valley and in the Snake River Valley in the vicinity of Nyssa, Ontario, and Weiser. Ground water has been developed from the volcanic and sedimentary aquifer units (Qal, QTv, QTs, and Tb) at several localities in the Malheur Basin (along Willow, Cottonwood, and Clover Creeks, and in Cow Valley), and at Jordan Valley and several scattered localities in the Owyhee Basin in Oregon.

In most of these alluvial valleys with large ground-water development there has been no decline in ground-water levels. Recharge is chiefly from large-scale and widespread irrigation with surface water diversions. Even with the increased ground-water withdrawals in recent years, water logging is still a common problem. Large additional quantities of ground water can be developed at many places in the valleys. A plan prepared by the Bureau of Reclamation in 1953 proposed the development of large quantities of ground water in the Boise Valley to replace part of the surface-water supply being used in the valley. (15) Surface water replaced in that way would be diverted to irrigate the plateau between Boise and Mountain Home. Thus, additional water would be made available for irrigation of large acreages, and water logging in presently irrigated lands would be alleviated.

Large areas of volcanic and sedimentary rocks (QTv, QTs, Tsv) are virtually unexplored and undeveloped in the Bruneau, Owyhee, and Malheur River drainages. At many places aquifers in these areas are probably capable of yielding moderate to large supplies. Although in much of the area the water table is many hundred feet below land surface (figure 356), the scanty hydrologic and topographic data available suggest that there are a number of basins where the water table is not more than a few hundred feet below land surface. Even though recharge is limited, perhaps equivalent to only 1 inch over the area annually, there probably is sufficient recharge to support local development at favorable locations; however, a concentration of withdrawal in a small area may lead to overdevelopment. Cow Valley in Malheur County is an example of such an area and has been declared a critical ground-water area by the Oregon State Engineer. The water level has declined beneath an area of more than 10 square miles because of annual withdrawal averaging 4,500 acre-feet from 12 wells since 1959.

Artificial Recharge

No intentional artificial recharge is being done in Subregion 5 at the present time. However, irrigation probably is the most important source of recharge and certainly is the most important recharge source to aquifers that will support the development of large, sustained supplies.

The alluvial deposits and younger volcanic rocks (Qal and QTv) are suitable for artificial recharge at many places and locally the younger sedimentary strata (QTs), the Tertiary basalt (Tb), and the silicic volcanic rocks (Tsv) may also be suitable. However, the alluvial deposits are saturated to near land surface in the central parts of most basins so there is little opportunity or need for additional artificial water storage in those places. South of the Snake River in the Bruneau and Owyhee highlands thick sections of unsaturated volcanic rocks (QTv and Tsv) are suitable for recharge; however, a source of water and the utility of storing large volumes of water in this area are not now apparent. A fairly thick section (200-700 feet) of unsaturated volcanic and sedimentary rocks (QTs, QTv) underlies the Mountain Home plateau between Boise and Mountain Home and the Sailor Creek area south of Glenns Ferry. These areas could be more easily recharged, and the water could be reclaimed for irrigation use.

The greatest opportunity for management of the water resources of Subregion 5 may lie in the conjunctive use of surface and ground water. Large irrigation projects could be planned to use surface water for only part of the supply. As the water table rose under the area, ground water would become readily available at favorable locations. Use of ground water as a part of the irrigation supply would not only reduce the amount of imported water necessary but also would help to prevent or alleviate water logging. The Mountain Home plateau and the Sailor Creek area are two areas that might be developed in this way.

Water Rights

Idaho

Considerable ground-water development under permits and licenses has occurred. This has been primarily in Owyhee County areas where surface water streams are essentially developed and artesian water is available. Recent ground-water development has taken place on the Mountain Home plateau. Use in some areas has resulted in several conflicts involving other well owners or individuals claiming rights to springs.

Nevada

Ground-water development within the Nevada portion of Subregion 5 has been on a very small scale and has been confined to the Owyhee River Basin. Development within this area has been principally from mine tunnels and shafts with six wells drilled for irrigation, two for stockwatering, one for the domestic use

Table 202 - Existing Nevada Ground-Water Rights, Subregion 5, 1969

Status	Irrigation and Mining (Cubic Feet Per Second)	Other	Reservoir Storage Rights (Acre Feet)
Certificates	1	0.2	2,760
Permits	4	-	360
Applications	8	-	2,640

and one for school use. The following table presents a summary of the ground-water rights in the Nevada portion of Subregion 5.

Oregon

In the Oregon part of the subregion, consisting essentially of the Powder, Malheur, and Owyhee Basins, primary water rights for 317 wells were on file with the State Engineer's Office as of March 1967. Primary rights allow withdrawal of 65,177 acre-feet a year, of which 41,660 acre-feet are for irrigation of 14,451 acres. The maximum rate of withdrawal is 191 cfs (85,500 gpm) during the irrigation season. Data on supplemental water rights are not available. Ground-water rights are summarized by major use category in table 202A as shown below.

Table 202A - Summary of Ground-Water Rights in the Oregon Part of Subregion 5, 1967

Basin No. & Name	Number of Wells	Domestic (ac-ft)	Municipal (ac-ft)	Industrial (ac-ft)	Irrigation (acres)	Irrigation (ac-ft)	Other (ac-ft)	Total (ac-ft)
9 Powder	110	104	5,650	3,015	5,168	15,505	2,013	26,287
10 Malheur	188	0	6,950	5,785	7,362	22,085	0	34,820
11 Owyhee	19	0	0	0	1,357	4,070	0	4,070
TOTAL	317	104	12,600	8,800	13,887	41,660	2,013	65,177

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

North of the Snake River Valley in Idaho and the Malheur River in Oregon, much of the subregion is mountainous. Precipitation at higher elevations ranges up to about 50 inches. Because most of this area is underlain by rocks of low or moderate permeability (pT, Tvs, Tb), the water table nearly everywhere is above stream level and aquifers are effluent to nearly all streams. The headwaters of the Boise, Payette, and Malheur Rivers have moderately

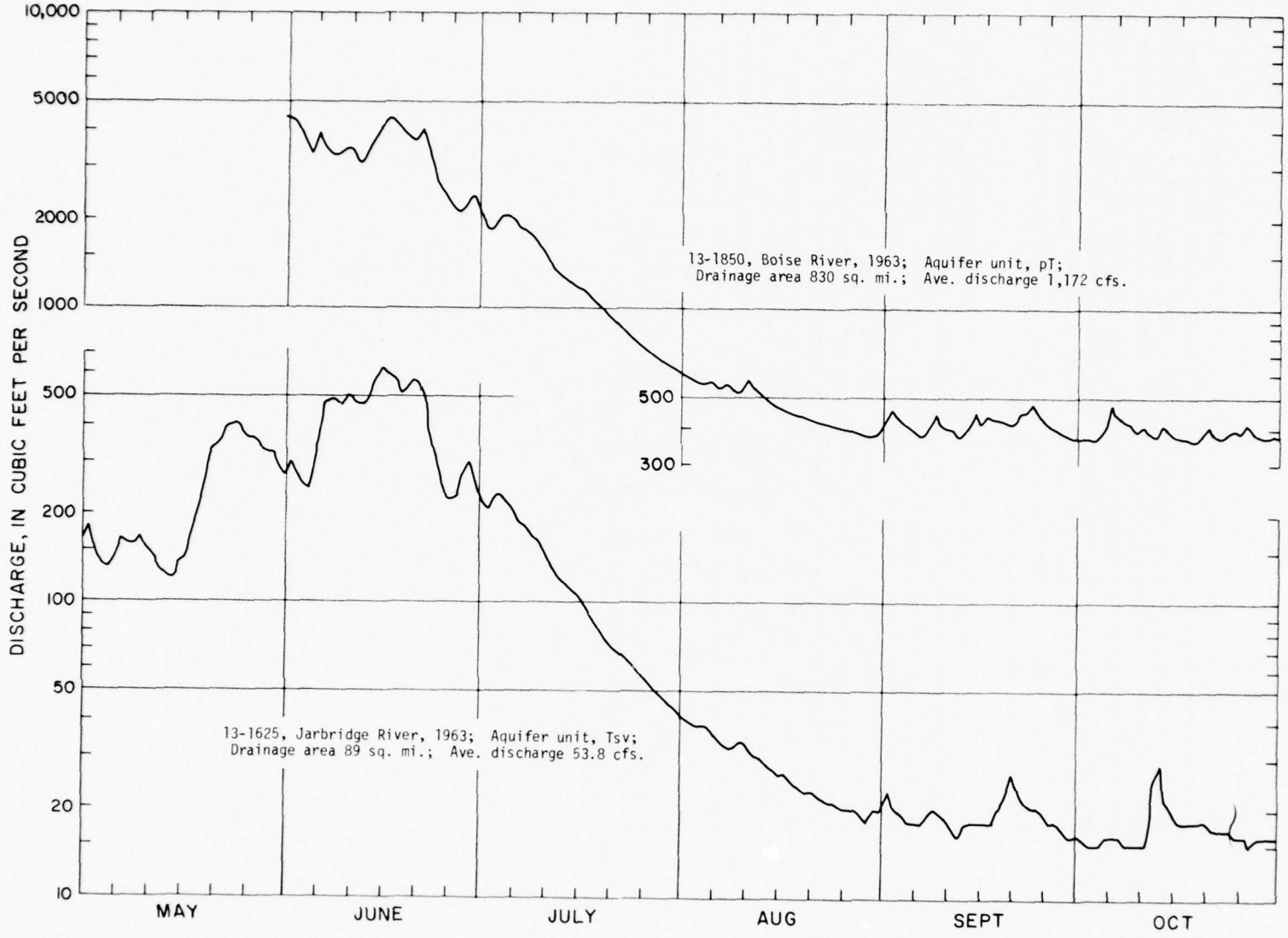


Figure 358 Hydrographs showing low-flow characteristics of selected streams

good base flow. Base flow in these rivers is maintained by ground-water inflow into hundreds of small tributaries, and the gently sloping recession curves (figure 358) indicate that flow is well sustained during the dry season. Large quantities of water are diverted from the Boise, Payette, and Malheur Rivers for irrigation of lands in the valleys. The lower reaches of these rivers and the Snake River receive large quantities of ground-water return flow. Dry season flows in these reaches are greater now than they were before the lands were irrigated.

The Owyhee Mountains in Idaho and the mountains in Nevada located south of the Snake and Malheur Rivers are underlain by rocks of relatively low permeability. These mountains receive 20 to 30 inches of precipitation. There are many springs in these areas and most streams receive perennial ground-water inflow. Most of the south half of the subregion is an arid to semiarid plateau underlain by moderately permeable to very permeable aquifers. The water table is usually deep; the infrequent small streams are generally far above the regional water table and are ephemeral and intermittent. Only trunk streams, such as the Jarbidge, Bruneau, and Owyhee Rivers, receive perennial ground-water inflow. In some reaches even some of the larger streams are above the regional water table. For example, the relative altitude of the water table and the water surface of the river suggest that the East Fork Bruneau River is above the regional water table (figure 356).

SUBREGION 6



LOCATION MAP

SUBREGION 6, LOWER SNAKE

HYDROLOGIC FRAMEWORK

The Lower Snake Subregion lies within the three states of Washington, Oregon, and Idaho, and includes a generally rectangular area comprising the lower Snake, Palouse, Clearwater, Salmon, and Grande Ronde River Basins, plus several smaller ones. The area is bounded on the north by the low Spokane River Divide, on the east by the Bitterroot Range, on the south by the Wallowa, Seven Devils, and Sawtooth Mountains, and on the west by the Blue Mountains and the low Palouse Hills of southeastern Washington. Mountain peaks about 11,000 feet, alpine valleys, deep canyons, rolling fertile prairies, and semiarid plains below 1,000-foot elevation all lie within the subregion. The area covers 35,081 square miles, of which 126 square miles are fresh water and 34,955 square miles are land, altogether amounting to about 13 percent of the regional area.

Figure 2 shows the general physiographic features of the subregion; parts of several geologic and physiographic provinces are included in Subregion 6. The Salmon and Clearwater River Basins are included in the Northern Rocky Mountain physiographic province. To the west, along the course of the Snake River and including the Blue Mountains, the area is included in the Wallowa-Seven Devils section of the Columbia Intermontane province. To the north lies the Palouse section of this same province. The rock types of the subregion are highly diversified, but the eastern Salmon River drainage and the Clearwater Mountains are primarily metamorphosed sandstones and shales and the lower Snake Tucannon, and Palouse Rivers cut into the basalt underlying the Columbia Plateau. Relatively undisturbed lavas are found in the Blue Mountains and Salmon River drainage and glaciation has been extensive in the Wallowa Mountains. The many mountain peaks rising to 10,000 feet, or more, are located around the subregion rim and in some of the ranges, but the northwest section is characterized by wide expanses of fairly flat land.

Streams originating in this subregion averaged about 12 1/2 inches of runoff per year or 32,400 cfs during the period 1929-58. The maximum annual runoff was about 2 times and the minimum about 1/2 the average.

The two principal streams are the Salmon and Clearwater Rivers, both of which flow through wilderness areas in which there are few roads. Stream gradients for the Salmon range from about 2 to 13 percent in the upper reaches, but are about 1/5 percent in the lower valley. The Salmon River Basin contributes about 11 inches of runoff per year. The Clearwater River stream gradients are low, ranging from about 1 to 3 percent in most of the upper reaches, and are less than 1/5 percent in the lower valley. However, the annual runoff of the Clearwater is about 21 inches.

Other streams include the Grande Ronde, Palouse, and mainstem Snake Rivers. For these the stream gradients range from about 1 to 13 percent in the upper reaches, but are less than 1/2 percent in the lower valleys, with the mainstem Snake having less than 1/8 percent. The Grande Ronde River Basin contributes about 11 inches of runoff per year, the Palouse, about 3 inches, and the entire Snake River Basin, nearly 6 inches.

About one-fifth of the subregion area is agricultural land, mostly in the Palouse and Clearwater Basins, farming being nearly all dryland. The Grande Ronde Basin and upper valleys of the Salmon River Basin have the only notable irrigation area. The soils of the Grande Ronde drainage have a wide variety, from gravelly loam to considerable silty clay. Much of the Blue Mountains has the Palouse-type soil, whereas some valleys in the Wallowa Mountains have sandy to gravelly soils characteristic of glacial outwash. About three-fifths of the area is forest land, mostly pine and fir, with other softwoods and noncommercial trees. The remaining fifth is semiarid desert with sage brush and sparse grass.

The cities of Lewiston, Idaho, and Clarkston, Washington, on the Snake River are the largest, with a combined population of 18,900 in 1960. However, just outside the subregion, at the mouth of the Snake River, the cities of Pasco and Kennewick had a combined population of 28,800 in 1960.

CLIMATE

This subregion has the most heterogeneous climatological conditions of any part of the Snake River Basin. A variety of factors, chief among them being the wide range in elevation, contribute to this situation. Eastward-moving Pacific maritime air masses, though modified by intervening topographic barriers to the

west, have a moisture content sufficient to produce considerable precipitation upon being lifted over the mountains within the area. The Clearwater River Basin, in particular, is so oriented that moist Pacific air entering the lower portion of the basin is subjected to marked vertical lifting. Other portions of the subregion, while having less rainfall opportunity and less efficient rain-producing features, receive reasonably large amounts of precipitation because of topographic variation. Of the entire Snake River Basin, this subregion has the smallest percentage of definitely arid area.

Precipitation

Precipitation varies through a wide range under the influence of differences in elevation and topography. Near the mouth of the Snake River, at an elevation of less than 400 feet, the average annual precipitation is about 7 1/2 inches. Eastward to the Idaho border the average increases to about 20 inches, although low-level locations, such as Clarkston and Lewiston, receive little more than 13 inches. On the elevated prairies or plateaus to the north and south of the Clearwater River, the annual average rises to 22 to 25 inches, and, farther east and southeast in the mountainous areas, annual totals range from 25 to more than 50 inches. Far upstream, in the Salmon River drainage, valley stations receive only 7 to 9 inches where numerous high ranges to windward have greatly diminished the moisture content of the air arriving from the west. Table 203 and figure 359 show precipitation data and location of precipitation stations. In common with most of the Pacific Northwest, a large part of the subregion experiences a sharp drop in average monthly precipitation in summer, the combined July-August-September total often being less than the total for a single month in winter or spring. The winter months receive the greatest precipitation totals, but the semiarid valleys in the upper reaches of the Salmon are exceptions. There, the

Table 203 - Average Monthly and Annual Precipitation (inches), Lower Snake Subregion, 1931-60

Station	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Colfax 1 NW	1,973	2.55	1.93	2.14	1.54	1.41	1.64	.46	.47	1.12	2.01	2.66	3.04	20.97
Lewiston WB AP[1/]	1,413	1.10	.97	1.18	1.14	1.55	1.73	.43	.43	.90	1.21	1.23	1.37	13.24
Pierce RS	3,175	4.82	4.42	4.39	3.47	3.29	3.26	1.07	.78	2.02	3.43	4.67	5.72	41.34
Kooskia	1,261	1.93	1.86	2.39	2.82	3.05	2.89	.85	.74	1.50	2.46	2.24	1.99	24.72
Grangeville	3,409	1.38	1.52	2.05	2.68	3.30	3.04	.88	.76	1.51	2.20	1.82	1.51	22.65
Salmon	3,949	.56	.50	.53	.64	1.38	1.35	.81	.56	.72	.66	.63	.59	8.93
Challis	5,171	.48	.33	.35	.53	1.11	1.18	.58	.53	.60	.46	.31	.47	6.93
Big Creek 1 S[1/]	5,686	2.93	2.53	2.32	2.03	2.45	2.30	.97	1.00	1.50	1.87	2.66	2.98	25.54
Riggins RS	1,801	.90	1.22	1.49	1.54	2.08	1.91	.62	.56	1.02	1.42	1.37	1.33	15.46
Union	2,765	.89	1.03	1.32	1.34	1.82	1.81	.46	.55	.76	1.22	1.25	1.22	13.70
LaGrande	2,786	1.99	2.01	2.13	1.91	1.90	1.96	.53	.53	.94	1.69	2.29	2.45	20.33
Meacham WB AP[1/]	4,050	4.20	4.00	3.96	2.80	2.45	2.45	.50	.53	1.46	2.84	4.15	4.53	33.87
Walla Walla 13 ESE[1/]	2,400	5.26	4.63	4.28	3.44	2.94	2.93	.66	.76	2.03	4.28	5.34	6.36	42.91

1/ Period is longer or shorter than the 30-year normal.

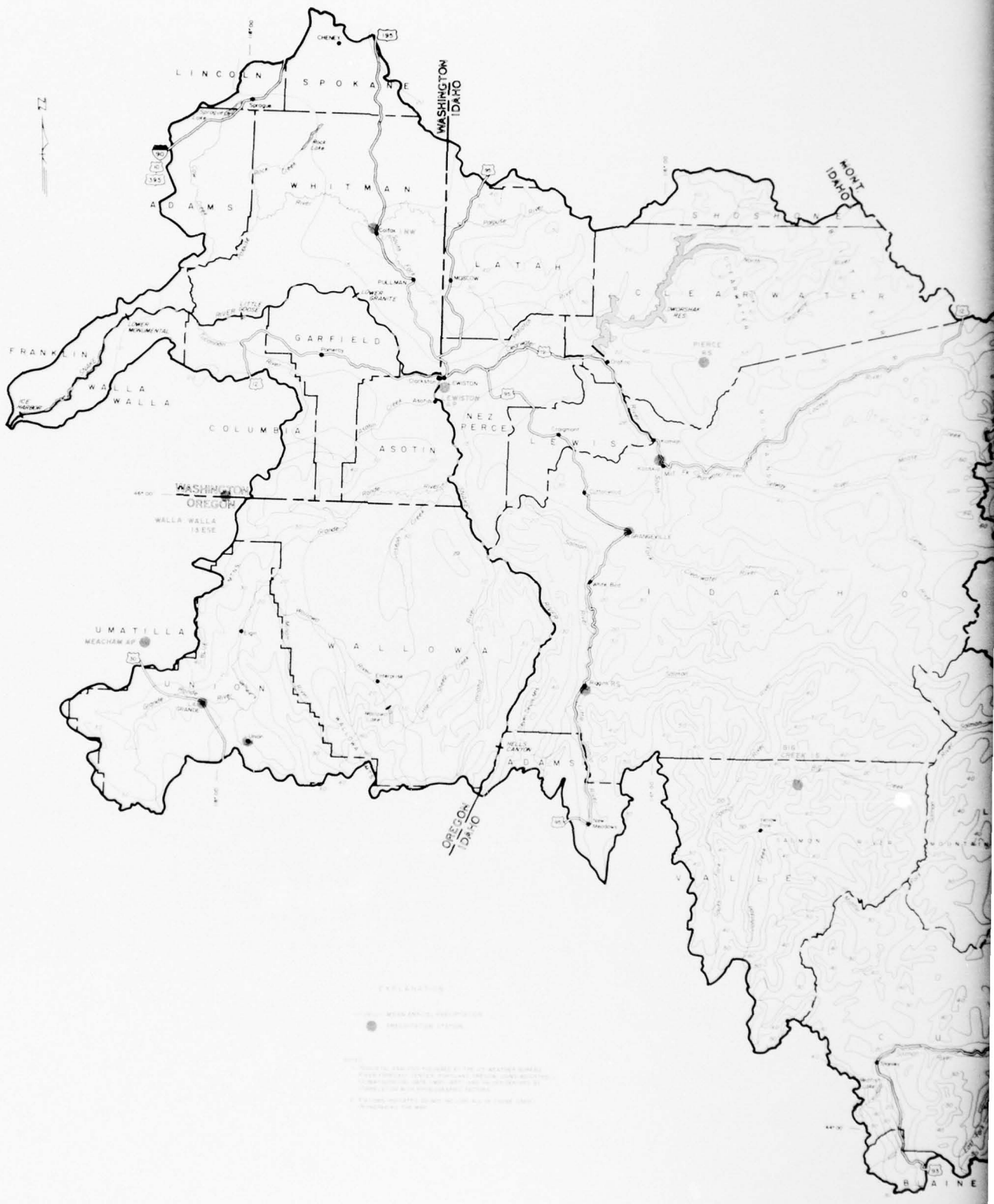
relatively frequent showers and thunderstorms in the warm season provide more precipitation than the winter storms. Several stations in the Lewiston-Grangeville area also show maximum monthly precipitation in May and June, in contrast to the marked winter maximum at a majority of locations in the subregion.

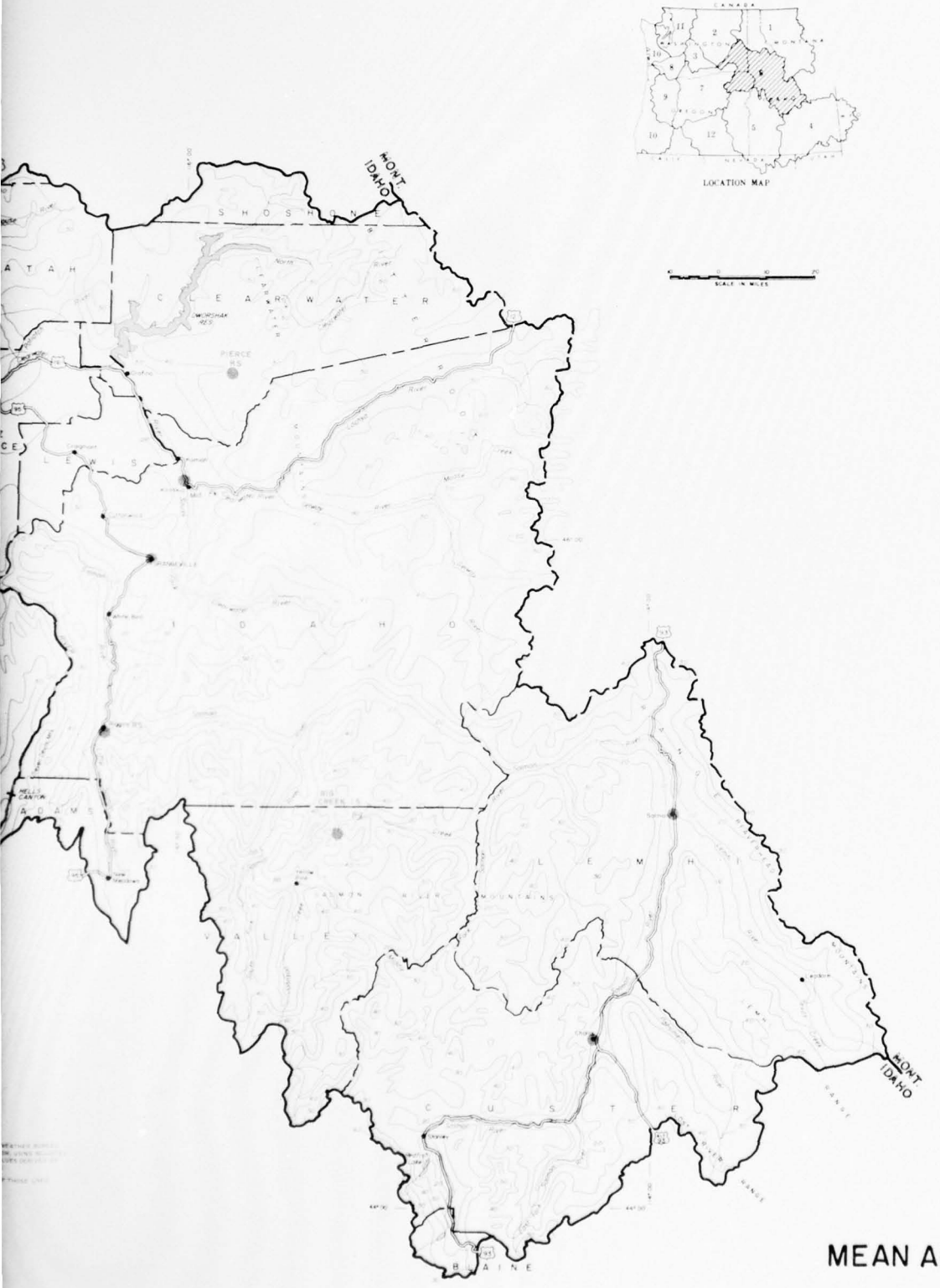
Figure 359 is an isohyetal map prepared by the Weather Bureau River Forecast Center, Portland, Oregon, using climatological data (1930-57) and information derived from correlations with physiographic factors.

Snowfall, which constitutes the larger portion of precipitation at high elevations and practically isolates many areas, occurs irregularly at the low elevations, even in mid-winter. Total annual snowfall exceeds 150 inches in some high valleys within the wilderness areas and probably exceeds 200 inches in many mountain locations, but is generally less than 20 inches at elevations of 1,500 feet or lower. The first 1-inch snowfall in autumn can be expected in October at higher elevations, in the latter half of November at elevations of 3,000 to 4,000 feet and in December at low elevations. The probability of accumulated snow reaching a depth of one foot is close to zero in the low level canyons and valleys, increasing to 1.0 at high elevations, while accumulations of 2 feet or more are almost entirely limited to the mountainous parts of the subregion. Snow course measurements at some of the higher levels reveal average accumulations of 50 to 100 inches on April 1, with water content of the snowpack 35 percent to 40 percent. Surface runoff from the high-level snowpack usually continues well into June.

Temperature

The range of temperatures reflects the wide range of elevation. Near the mouth of the Snake River the mean annual temperature is approximately 54°F. while in the Sawtooth Valley, in the upper portion of the Salmon River Basin at an elevation of close to 7,000 feet, the annual mean is about 35°F. The average number of days per year with maximum temperature of 90° F. or higher ranges from 50 or 60 in the canyons of the Little Salmon and the Clearwater, to practically none in the Sawtooth Valley. Minimum temperatures of 32°F. or lower are recorded on less than 100 days per year near the mouth of the Snake, on the average, but on 300 days or more at high elevations. Freezing temperatures are likely in all months at the higher levels. Temperatures of 0°F. or lower occur on an average of more than 50 days per year in the Sawtooth Valley, but on only 2 or 3 days at elevations of around 1,500 feet


LINCOLN
SPOKANE
WASHINGTON
IDAHO
MONT
IDAHO
ADAMS
WHITMAN
LATAH
CLEARWATER
FRANKLIN
GARFIELD
WALLA
WALLA
COLUMBIA
ASOTIN
NEZ
PERCE
LEWIS
WASHINGTON
OREGON
UMATILLA
WALLOWA
UNION
OREGON
IDAHO
IDAHO
BAINE



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COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL PRECIPITATION IN INCHES

LOWER SNAKE SUBREGION 6

1968

FIGURE 359

Table 204. Average and Extreme Temperatures (°F), Lower Snake Subregion

Station	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Lewiston WB AP 1/	Av. Max.	36.5	44.6	51.8	62.3	71.0	77.7	89.0	86.3	78.2	62.7	47.6	41.7	62.5
(14)	Av. Min.	22.5	28.6	32.3	38.4	45.8	51.6	57.2	55.4	48.7	40.0	31.9	28.7	40.1
	Mean	30.7	35.9	42.6	50.8	58.4	64.8	73.8	71.7	63.5	52.0	39.8	34.9	51.6
	Highest	66	65	76	87	96	100	109	104	103	85	71	60	109
	Lowest	-22	-15	2	22	23	34	41	43	30	21	-3	2	-22
Pierce RS 1/	Av. Max.	32.2	37.7	44.7	54.9	66.6	73.0	85.0	83.2	73.6	59.6	41.3	33.7	57.1
(23)	Av. Min.	14.1	17.9	21.8	28.1	37.2	43.0	45.0	41.8	37.1	31.7	24.9	19.6	30.2
	Mean	23.1	27.9	33.2	41.5	51.8	57.9	65.0	62.5	55.3	45.6	33.1	26.7	43.6
	Highest	59	61	72	90	97	100	107	100	103	88	66	52	107
	Lowest	-34	-44	-24	4	21	25	30	28	12	2	-19	-25	-44
Grangeville	Av. Max.	35.4	39.5	45.9	55.3	63.3	70.0	82.4	82.3	71.2	58.6	45.4	38.6	57.3
(38)	Av. Min.	19.9	23.3	27.6	33.9	40.0	45.4	51.5	50.2	43.1	36.2	27.8	23.5	35.2
	Mean	27.7	31.5	36.9	44.9	52.2	57.9	67.0	65.9	58.1	47.8	36.4	31.3	46.5
	Highest	59	64	74	86	96	98	108	102	104	85	70	66	108
	Lowest	-24	-24	-9	11	19	31	33	34	25	3	-17	-17	-24
Salmon	Av. Max.	29.5	37.0	46.7	62.2	70.7	78.1	88.7	86.5	75.8	62.8	43.7	32.2	59.5
(52)	Av. Min.	5.7	12.1	22.4	29.4	36.6	42.9	47.3	44.2	36.6	28.2	19.3	10.6	27.9
	Mean	17.9	24.7	35.1	45.7	53.9	60.2	67.8	65.6	56.6	45.8	31.8	22.5	44.0
	Highest	62	68	75	89	96	100	106	103	99	87	78	62	106
	Lowest	-37	-35	-25	2	16	25	26	22	13	-1	-18	-32	-37
Union	Av. Max.	35.7	41.3	50.1	60.1	67.6	73.9	84.0	83.0	73.8	61.6	47.6	38.9	59.8
(50)	Av. Min.	22.6	26.3	29.6	33.8	39.2	44.5	48.7	46.5	40.3	35.3	30.5	25.9	35.3
	Mean	29.8	33.9	39.9	47.4	53.8	58.9	66.4	64.6	57.9	49.2	38.9	33.7	47.9
	Highest	61	67	77	86	92	101	103	101	101	87	72	62	103
	Lowest	-27	-21	-10	9	20	29	32	28	18	14	-12	-24	-27
Walla Walla	Av. Max.	32.6	40.0	47.2	59.5	67.2	73.0	84.5	81.4	73.5	58.7	42.5	36.9	58.1
13ESE 1/	Av. Min.	20.6	25.6	28.1	33.6	38.5	42.9	45.9	44.3	40.4	35.2	28.8	25.9	34.2
	Mean	26.6	32.8	37.7	46.6	52.9	58.0	65.2	62.9	57.0	47.0	35.7	31.4	46.2
	Highest	57	63	75	84	89	95	102	100	97	81	62	68	102
	Lowest	-18	-16	-1	24	20	30	34	34	26	17	-8	0	-18

1/ Period is longer or shorter than the 30-year normal.
Note: The mean temperature is for the normal period 1931-60; other data are for the period of record through 1960. Numbers under station names denote full years of record for all data.

and lower. The large diurnal temperature range, so typical of inland areas of the western United States, is quite apparent in summer. The difference between mean daily maximum and minimum temperatures in July ranges from 30°F. or more at low elevations to more than 40°F. at higher elevations. In winter, when cloudiness often blankets the region, the diurnal range is 15° or less at low levels and 25°F. at high valley stations. Table 204 and figure 359 show temperature data and locations of weather stations.

The growing season, based on the period between last 32°F. temperature in spring and first in fall, averages about 160 to 180 days in the warmest localities of the subregion, 110 to 130 days on the prairies north and south of the Clearwater River, and is about zero days in the Sawtooth Valley and other high level areas. At Moscow, Idaho, in the Palouse River Basin it is 146 days long; at La Grande, Oregon, in the Grande Ronde River Basin it is 143 days; and at Challis, Idaho, in the upper Salmon River Basin it is only 108 days. The average date of the last spring freeze is May 9 at Moscow, May 9 at La Grande, and May 31 at Challis. The average date of the first fall freeze is October 3 at Moscow, September 29 at La Grande, and September 15 at Challis. For the 28°F. threshold the growing season averages about 30 to 50 days longer than for 32°F.

Wind

Surface winds are affected so much by topography that it would be futile to attempt a generalized description for this subregion. A study by Bonneville Power Administration on extreme winds indicates that an extreme 1-minute average wind speed of 45 to 50 mph can be expected once in 2 years, on the average, 55 to 60 mph once in 10 years, and 70 to 80 mph once in 50 years, in the subregion.

Evaporation

Mean annual evaporation from pans ranges from more than 50 inches in the warmer portions of the region to less than 40 inches at the higher, cooler elevations. Evaporation from lakes and reservoirs ranges from around 40 inches to less than 30 inches with more than 80 percent of the loss occurring in the 6-month period May through October. Potential evapotranspiration is estimated at 22 to 28 inches per year in the warmer portions of the region and less than 20 inches in the cool, high level areas. At lower levels, where summer temperatures are high and precipitation light, the actual evapotranspiration is estimated at about 65 or 70 percent of the potential on soils with an available water capacity of 6 inches, but little more than half of the potential on shallow soils. At higher elevations, where precipitation is adequate and temperatures more moderate, the actual would approach the potential evapotranspiration.

Storms

Significant storms affecting the subregion are of Pacific Ocean origin and occur during the winter season; the most severe ones have had a long trajectory over the Pacific. Typical of such great storms was that of November 1909. For high-intensity rates of measured rainfall occurring over periods of time up to 24 hours, this storm was without parallel in many parts of the Northwest, including parts of the Snake River Basin.

Of nine great storms of record, excluding localized convective storms, three occurred in November, four in December, and one each in March and May. Those storms that occur during the spring season usually are of local significance and may cause appreciable damage over small areas. Greatest areal values, however, occur as a result of general winter storms. Thunderstorms, while of frequent local importance, are not significant to the subregion as a whole. Hail or sleet storms are common, as are twisters or "dust devils," and occasionally a tornado will cause severe damage over a small area of 10 square miles or less.

Humidity

Relative humidity data are available only for low-elevation areas of the subregion. During midsummer, the late afternoon readings average less than 25 percent, with early morning readings of 50 to 60 percent, while in winter the daily variation is small with average readings of 75 to 80 percent.

Sunshine

Cloudiness also shows a marked variation from summer to winter. During July, only about 3/10 of the sky is covered by clouds on the average, but, from November through February, the sky cover averages 8/10 or more. Sunshine averages about 60 percent of possible on an annual basis, ranging from around 20 percent in December to 85 percent in July and August.

SURFACE WATER

The rivers of the Lower Snake Subregion are only partly used, the water supply is moderate but well distributed and the quality of water is very good. The runoff is primarily from spring snowmelt, with varying amounts of rain runoff included. There is no flood control storage in the subregion, but the new Dworshak reservoir provides a large block of such storage, and the Snake River Basin is well regulated by upstream reservoirs.

Water is used for power generation at four lower Snake River dams, Dworshak Dam and Wallowa Lake.

Although irrigated areas are small, they are numerous throughout the subregion. Water is stored for irrigation and other purposes in seven reservoirs exceeding 5,000 acre-feet in total capacity, most of them being on the mainstem lower Snake River.

Navigational use of water is important on the mainstem Snake River up to Lewiston, with pleasure boating and miscellaneous minor traffic continuing still farther upstream.

Quantity

Average discharge of streams originating in the subregion totals about 32,380 cfs (23.4 million acre-feet annually). This averages 0.92 cfs per square mile, an intermediate rate in the Columbia-North Pacific Region.

Present Utilization

About 4.1 percent of the average discharge was withdrawn in 1965 for consumptive uses, but only about 1.4 percent was actually consumed. About one-thirtieth of the water withdrawn for consumptive uses (about 1,320 cfs) is for municipal supplies (30 cfs domestic and 9 cfs industrial); the largest user is irrigation (1,094 cfs), and it is the major consumer 444 cfs of the total of 465 cfs. There is a minor amount of steam power generation. Most of the subregion's runoff passes through several hydroelectric plants. Navigation use of water is mostly by barges and tugs. Recreational use of water is popular and growing, although the water surface area for it is small in this subregion. All waters are used to some degree for fish and wildlife. Although water is but moderately copious in this subregion, pollution is a problem only on some of the smaller streams.

Stream Management

Competition for water among the various users necessitates efficient stream management. Storage and release, diversions, conservation, legal constraints, etc. all are a part of the water-management system.

Impoundments Reservoirs having a total capacity of 5,000 acre-feet or more are listed in table 205. Dworshak Reservoir on the North Fork Clearwater River is the largest impoundment in the subregion, but the four lower Snake Reservoirs are also large, Ice Harbor, Little Goose, Lower Granite, and Lower Monumental reservoirs. Five reservoirs are multiple purpose to the extent that at least four purposes were specified in their design.

Table 205 - Reservoirs Having a Total Capacity of 5,000 Acre-Feet or More, Subregion 6

Name	Stream	Total Storage (acre-feet)	Active Storage (acre-feet)	Surface Area (acres)	Purpose[1/]
Dworshak	N. F. Clearwater R.	3,453,000	1,433,000	16,970	FNPR
Hells Canyon	Snake R.	164,000	16,000	-	P
Ice Harbor	Snake R.	406,000	25,000	9,000	INPR
Lake Waha	Lake Cr.	6,900	-	-	I
Little Goose	Snake R.	565,000	49,000	10,000	INPR
Lower Granite	Snake R.	484,000	44,000	8,900	INPR
Lower Monumental	Snake R.	376,000	20,000	6,590	INPR
Reservoir A	Sweet Water-Web Cr.	-	6,680	6,680	IM
Wallowa Lake	Wallowa R.	42,750	37,450	1,670	IP

1/ I-irrigation, F-flood control, M-municipal, N-navigation, P-power, R-recreation.

Operation of Dworshak Reservoir, where snowmelt is the primary cause of runoff, generally follows a pattern of filling during May, June, and July, then slow evacuation for power production until January, and final evacuation by May for flood control.

The impoundments have variable short-term effects on river discharge. The changes in discharge due to power loads are abrupt and, on weekends when less power is required, flows may be low. Municipal water is supplied during the summer, principally to satisfy lawn-watering and air-conditioning needs. Irrigation water is supplied at a fairly constant rate from April through September. On the other hand, recreational use requires that the water be retained in the reservoirs as long as possible during the summer.

Diversions Most of the diversions in the Lower Snake Subregion are for irrigation. Other diversions are made for municipal, industrial, and drainage uses. Although there are many diversions, the quantity of water involved is small. The largest diversions are in the Grande Ronde River Basin.

Channel Modification Channel modification has taken place in the Grande Ronde River, Palouse, and, to a minor extent, in the Snake River. Log jam removal and revetment construction has been carried out on other tributary streams within the subregion. Some local levees have been constructed along Salmon River, Catherine Creek, Tucannon River, and several tributaries of Clearwater River.

Forecasting Forecasting is used in flood control operations of reservoirs, flood warning, and to provide a maximum of stored water for power generation, municipal use, and irrigation, consistent with assured refill of the reservoirs. The Weather Bureau is officially responsible for providing a flood-warning service to the general public at times of major flooding.

Forecasts of seasonal quantities of water available for storage are made using snow-survey data, precipitation data, and data on antecedent conditions, and other parameters. The information is processed by digital computer and updated each month as new data are obtained.

Constraints There are several compacts and treaties that are concerned with runoff in the Columbia River and tributaries. These are discussed in the Regional Summary, along with general constraints.

Water Rights

Idaho Rights to use of water from the mainstem of the Lower Snake River in Idaho consist mainly of permit rights for power purposes. Except for extreme high flows, the entire flow of the river passes through the power plants. The water permits for power were issued with the condition, however, that use of the water would not interfere with future upstream uses which may cause a depletion of the flow of the Snake River.

Rights to the use of considerable quantities of water of the Salmon River and its tributaries have been determined by court action. This is particularly true in the Lemhi and Pahsimeroi River tributaries where irrigation rights are adjudicated and in other streams where water has been used for mining. The adjudicated irrigation rights in the Lemhi River are on most of its smaller tributaries, while no water rights from the Lemhi River proper have been established by the court.

Much water is used for fishing, recreation, and pleasure boating, but rights of this nature have never been adjudicated in Idaho.

There are no adjudicated rights of any consequence in the Clearwater River. There are uses for irrigation of some areas and for industry and power, which are under permit and license. Considerable use is made of the Clearwater River and its tributaries for outdoor recreation purposes.

In general there is considerable unappropriated water in the Lower Snake River in Idaho with the exception of certain tributary streams in the Salmon River Basin, where the base flow has been allocated for irrigation purposes.

Washington In that part of the Lower Snake Subregion located in the State of Washington, essentially Water Resource Inventory Areas 33 through 35 (figure 360), a total of 259 active surface-water right appropriation records, in permit and certificate stages, was on file with the Department of Water Resources on April 30, 1967. Prime rights in this area allow summer period diversions totaling 480.43 cfs of which consumptive diversions amount to 438.20 cfs, partially consumptive diversions account for 12.23 cfs, and nonconsumptive diversions are permited to 30.00 cfs. A total of 5.56 cfs has been appropriated under supplemental rights.

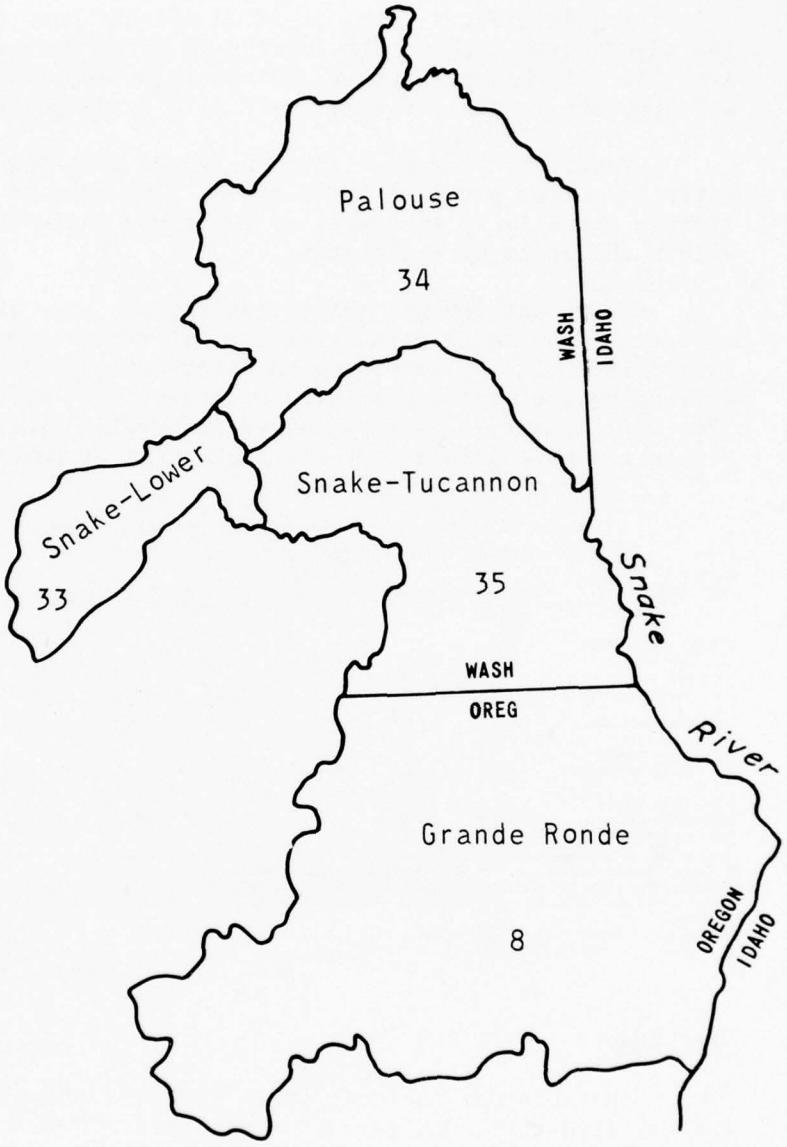


Figure 360 Map showing water resource inventory areas defined by the State of Washington Department of Water Resources and the State of Oregon Water Resources Board.

In addition, a total of 22.09 cfs has been granted under 164 adjudicated rights, all located in Water Resource Inventory Area 35. Of this quantity 17.09 cfs is consumptive to the resource and 5.00 cfs is classified as partially consumptive.

Reservoir storage rights on record with the Department of Water Resources permit a total of 925 acre-feet to be retained in storage annually in that part of the Lower Snake Subregion located within the State of Washington.

Prime water right quantities for the more important use categories and total actual surface water right quantities are listed in table 206 according to Water Resource Inventory Areas as defined by the State of Washington, Department of Water Resources (Regional Summary). More detailed information about specific rights can be obtained from the Department of Water Resources.

Table 206 - Surface Water Rights, Snake Subregion, 1967

Basin No.[1]	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total[2]	Reservoir Storage Rights
		(Cubic Feet per Second)							(Acre-Feet)
Appropriative Rights									
33	Snake-Low	-	233.61	-	-	-	-	234.05	-
34	Palouse	-	99.58	1.87	0.20	25.00	0.03	125.71	881
35	Snake-Tucannon	67.24	96.88	0.21	-	16.50	0.11	120.67	44
Appropriative Totals		67.24	430.07	2.08	0.20	41.50	0.14	480.43	925
Adjudicated Rights									
35	Snake-Tucannon	-	16.87	9.08[3]	-	-	9.08[3]	22.09[4]	-
Adjudicated Totals		-	16.87	9.08	-	-	9.08	22.09	-
Combined Totals (Approp. & Adjud. Rights)		67.24	446.94	11.16	0.20	41.50	9.22	502.52	925

1/ Water Resource Inventory Area number as shown in figure 360.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed and (2) water right quantities that are common to two or more uses are listed under each applicable use category.
3/ Quantity is common with irrigation use.
4/ Includes 5.00 cfs for hydroelectric power generation.

Discharge

The water discharge picture includes measurement, location, timing, frequency, and variation of the river flows for some standardized period of years. The base period selected for the Columbia-North Pacific Region study is the 30-year interval 1929-58. A typical Subregion 6 stream, Clearwater River at Kamiah, Idaho, shows a base-period mean discharge equal to 94 percent of its long-term mean (55 years, 1911-1965). Weather records show that precipitation in Lewiston during the base period was 96 percent of the long-term mean (88 years, 1878-1965). Thus, the selected base period provides reasonably average data for statistical analysis.

Measurement Facilities Measurement facilities comprise primarily the gaging stations and their characteristics where the measurements are made. Table 207 summarizes pertinent streamflow data for the 12 sites selected for detailed study in Subregion 6.

Figure 362 shows the locations of the selected sites, with Geological Survey identification numbers. The numbers correspond to those of table 207, but are often shown with additional leading digits to indicate the general area or part number as follows: Part 12, Pacific slope basins in Washington and upper Columbia River Basin; Part 13, Snake River Basin; and Part 14, Pacific slope basins in Oregon and lower Columbia River Basin.

Table 207. Streamflow Summary for Selected Sites
Subregion 6

Stream	Station	Station Number	Gage Datum	Drainage Area (Sq. Mi.)	Period of Record	Annual Flows 1/ (cfs) Mean	Max.	Min.	Momentary Flow 2/ Max.	Min.
Salmon River	Challis	2985	5163.92	1,800	1928-65	1,459	2,344	855	15,400	160
Salmon River	Salmon	3025	3911.14	3,760	1919-65 3/	1,898	2,911	1,157	16,500	242
Salmon River	French Creek	3150	1908.92	12,270	1944-56	9,230	13,770	4,957	88,600	1,790
Salmon River	Whitebird	3170	1412.65	13,550	1919-65	10,690	15,891	5,792	106,000	1,580
Grande Ronde	Rondowa	3325	2281.87	2,555	1926-65	2,044	3,271	1,175	24,700	225
Selway River	Lowell	3365	1540	1,910	1929-65 3/	3,604	4,926	2,233	48,900	100
Lochsa River	Lowell	3370	1452.98	1,180	1929-65 3/	2,712	3,742	1,581	35,100	100
Clearwater River	Kamiah	3390	1162.52	4,850	1910-65 3/	7,674	11,170	4,755	103,000	179
Clearwater River	Spalding	3425	770.5	9,570	1925-65 3/	14,573	22,447	9,826	177,000	500
Snake River	Clarkston	3435	670	103,200	1915-65	45,850	65,489	31,206	369,000	6,660 4/
Palouse River	Hooper	3510	1040	2,500	1951-65 3/	543	1,072	256	33,500	0
Snake River	Ice Harbor Dam	3530	m.s.l.	108,500	1907-17 1962-65	45,984	66,398	31,029	298,000	11,800

1/ Regulated values for base period (1929-58) with estimated 1970 conditions of development.
2/ Maximum and minimum observed instantaneous values for period of record.
3/ Denotes other short periods of record prior to dates shown.
4/ Caused by construction closure at Brownlee Dam. Natural minimum about 10,600 cfs.

Average Discharge for Subregion 6 Figure 361 presents monthly discharge data for the subregion as a whole. The discharge is the sum of the Snake River flow and that generated within the subregion, less certain unidentified flows or losses such as storage changes, inflow from ground-water springs, direct rainfall on streams, evaporation losses, deep percolacion, channel storage, and bank storage. The discharge begins an almost steady rise in October from rainfall and reaches its crest in May and June from snowmelt. The flows for both the Snake River and that generated within the subregion are listed in table 208.

The inflows to Subregion 6 are somewhat different from outflows from Subregion 5 because the latter have been modified according to a system of power loading devised by the Bureau of Reclamation, whereas the former conform to the recommended system of Bonneville Power Administration, study number 75-8. Either flows could represent the facts as of 1970.

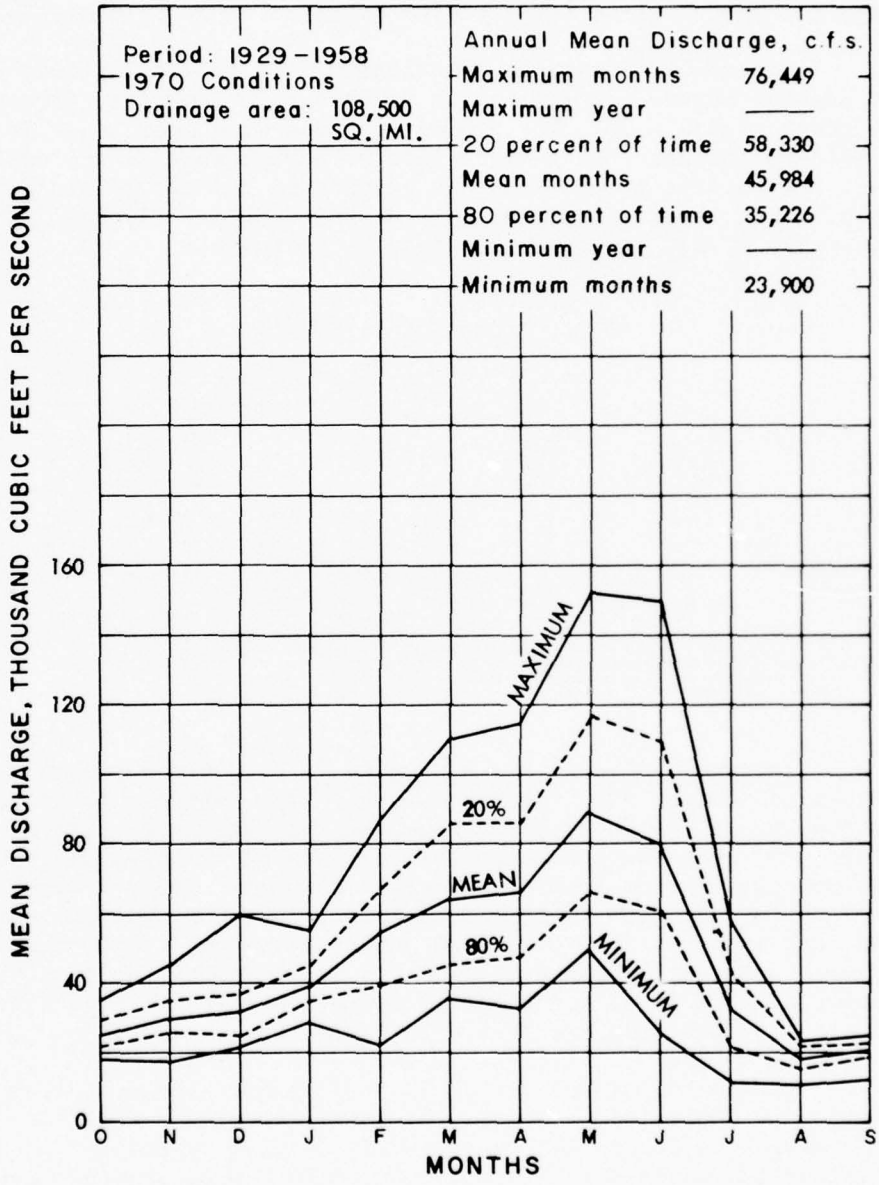
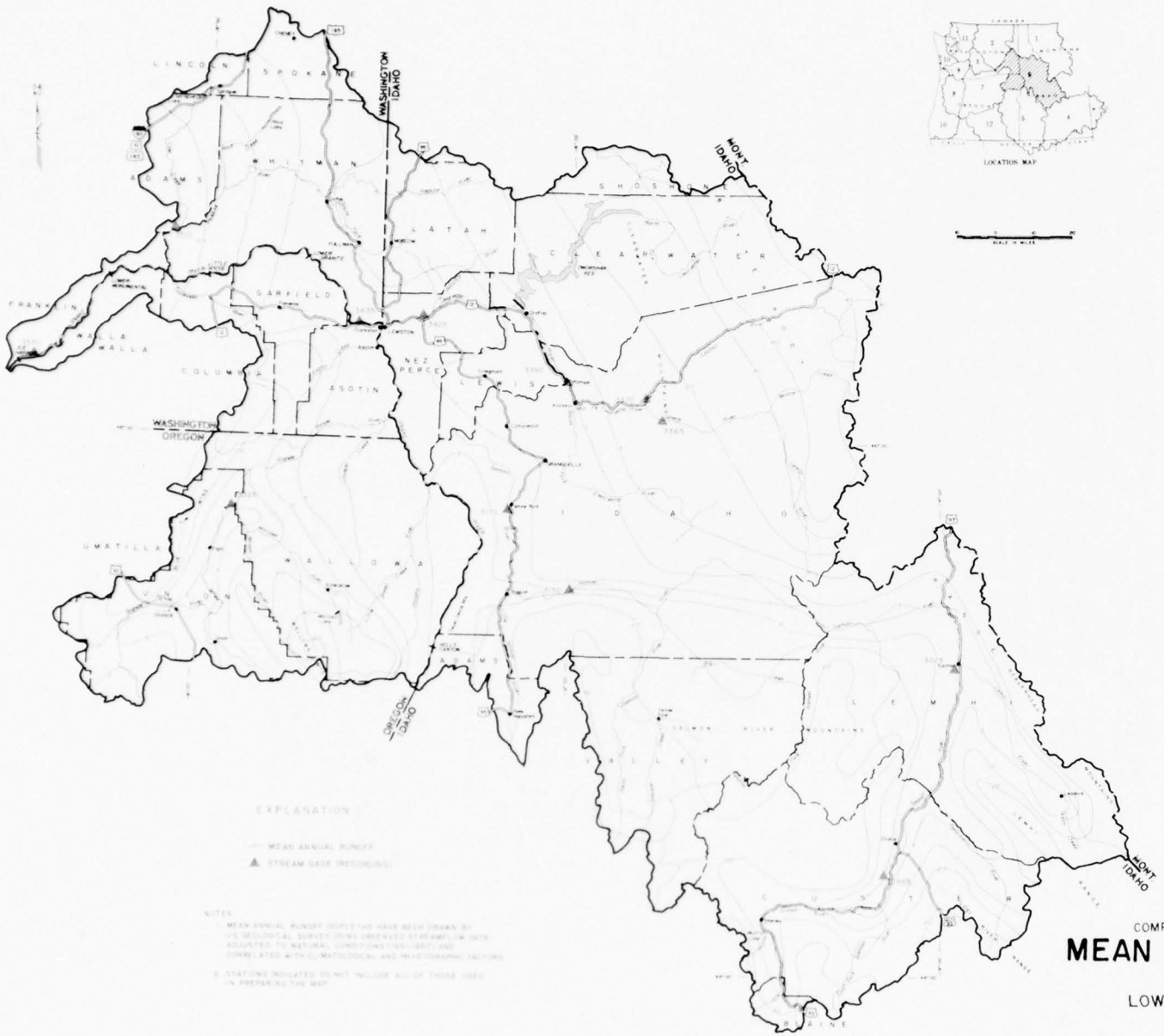


Figure 361 Monthly discharge, Lower Snake Subregion



LOCATION MAP

EXPLANATION

MEAN ANNUAL RUNOFF

STREAM GAGE (RECORDING)

NOTES

MEAN ANNUAL RUNOFF DEPICTED HAVE BEEN DRAWN BY U.S. GEOLOGICAL SURVEY USING OBSERVED STREAMFLOW DATA ADJUSTED TO NATURAL CONDITIONS (1931-60) AND CORRELATED WITH CLIMATOLOGICAL AND PHYSIOGRAPHIC FACTORS.

2. STATIONS INDICATED DO NOT INCLUDE ALL OF THOSE USED IN PREPARING THE MAP.

COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

MEAN ANNUAL RUNOFF IN INCHES

LOWER SNAKE SUBREGION 6

1968

FIGURE 362

Isopleths showing mean annual runoff for the period 1930-60 are shown on figure 362.

Average Discharge for Selected Stations In this section of the report, detailed data are presented for each of the selected sites listed in table 207. The monthly discharge data were originally available in Geological Survey Water-Supply Papers 1316, 1317, 1318 and 1736, 1737 and 1738, compilations of surface-water records in Parts 12, 13, and 14. These have been changed to the extent that they have all been termed modified mean discharges, as presented in tables 209 to 220. The modifications consisted of application of irrigation depletions, an assumed plan of reservoir regulations and extension of records for some sites by correlation with nearby stations. Hydrographs for several conditions of flow at the selected sites are shown on figures 363 to 374. It should be noted that, although High Mountain Sheep Dam is not expected to be existing or under construction by 1970, it was assumed that somewhat equivalent storage probably would be under construction by that time. Therefore, the effect of storage proposed for High Mountain Sheep Reservoir has been included in the modified flows of the mainstem Snake and Columbia Rivers.

It should also be noted that the supply of water indicated by the monthly discharge hydrographs is not necessarily available for development, even though it already reflects depletions and storage regulation. It may already be committed to some downstream use such as diversion to irrigation.

Explanations of the hydrographs and the succeeding graphs are given in the Regional Summary. Examination of the hydrographs indicates that all streams have considerable base flow except the Palouse River and much of the Clearwater River. The Palouse is the only stream with practically all of its runoff occurring early due to rainfall.

Frequency curves of annual high and low discharges are shown on figures 375 to 386. The slopes of the curves of high flows are high for the upper Salmon and Clearwater Rivers and Palouse River, and they are moderate for the Grande Ronde and Snake Rivers. The low-flow curve slopes tend to show the opposite effects. The spread of the high-flow curves is again high for the upper Salmon and Clearwater Rivers and Palouse River. The spread for low-flow curves is fairly high for all streams except in the upper Salmon River Basin for durations up to 183 days.

Table 208. Discharge in Lower Snake Subregion, 1929-58
(Mean Discharge, in cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
						Maximum							
Total	35,188	44,871	60,104	54,860	87,542	110,224	114,956	151,890	150,477	58,250	23,900	25,123	76,449
Oxbow	16,170	16,380	20,516	23,969	37,414	43,994	51,016	53,990	31,810	16,239	11,156	13,245	27,992
Unidentified	-1,242	-1,079	-7,732	-10,679	18,418	11,910	-30,930	-40,740	-23,933	-21,199	-12,706	-1,372	-10,107
Subregion	20,260	29,570	47,320	41,570	31,710	54,320	94,870	138,640	142,600	63,210	25,450	13,250	58,564
						20 Percent							
Total	29,016	35,413	37,393	44,875	67,383	85,893	85,628	117,026	109,397	42,610	22,207	23,122	58,330
Oxbow	14,337	15,482	17,886	20,101	24,819	33,981	37,350	22,920	25,650	10,850	10,220	12,290	20,490
Unidentified	-721	-1,729	-2,023	-986	14,704	13,452	-15,992	-19,334	-22,723	-5,300	-1,643	-1,358	-3,638
Subregion	15,400	21,660	21,530	25,760	27,860	38,460	64,270	113,440	106,470	37,060	13,630	12,190	41,478
						Mean							
Total	25,017	30,447	32,131	39,650	54,464	64,337	65,796	88,618	79,913	32,197	18,570	20,670	45,984
Oxbow	13,034	14,198	15,977	17,497	20,545	24,423	23,522	18,493	15,839	8,603	9,129	11,282	16,045
Unidentified	-1,420	-1,357	-822	1,425	12,797	10,588	-10,284	-18,016	-14,683	-4,253	-2,322	-899	-2,437
Subregion	13,403	17,606	16,976	20,728	21,122	29,326	52,558	88,141	78,757	27,847	11,763	10,287	32,376
						80 Percent							
Total	21,570	26,241	25,309	35,144	39,433	44,917	47,792	65,706	60,192	21,822	15,912	18,680	35,226
Oxbow	12,220	12,938	14,636	15,445	16,709	16,492	14,730	11,959	6,213	5,594	8,998	11,157	12,258
Unidentified	-1,670	-37	1,123	4,039	6,304	7,705	-6,128	-13,233	-891	-142	-2,486	-1,297	-560
Subregion	11,020	13,340	9,550	15,660	16,420	20,720	39,190	66,980	54,870	16,370	9,400	8,820	23,528
						Minimum							
Total	18,100	17,429	21,977	28,677	22,091	35,732	33,455	49,370	25,674	11,509	10,578	12,206	23,900
Oxbow	10,199	12,127	11,990	12,475	10,796	12,710	8,766	5,000	5,000	5,000	5,000	5,000	8,672
Unidentified	261	-3,278	2,147	7,462	1,075	9,082	-2,291	-11,510	-5,066	-2,861	-882	416	-454
Subregion	7,640	8,580	7,840	8,740	10,220	13,940	26,980	55,880	25,740	9,370	6,460	6,790	15,682

NOTE: 1. Subregion discharge is that which originates in the subregion.
2. 20 percent and 80 percent represent the discharge available 20 and 80 percent of the time.
3. Unidentified flows include storage changes for High Mountain Sheep or alternative reservoir capacity of about 2.2 million acre-feet, inflow to main streams from ground water springs, water from atmosphere falling directly on main streams, evaporation and evapotranspiration losses, deep percolation, channel storage and bank storage. Of these items, reservoir storage and channel storage account for a large part of the variations shown.

Duration curves for three flow conditions, daily, monthly, and annual, are presented in figures 387 to 398. The monthly and annual discharges used are those of tables 209 to 220, but the daily flows are observed for the period of record as provided in Geological Survey daily summaries. Slope of the annual curve is greatest for the Palouse River and departure of the monthly from the annual curve is greatest for the Palouse and upper Clearwater Rivers but least for the Snake and upper Salmon Rivers.

Frequency curves of annual peak flows are shown in figures 399 to 410. Most curves are for unregulated conditions; both unregulated and regulated conditions are shown for the mainstem Snake River and the Clearwater River below Dworshak Reservoir. The curve with greatest slope is that for the Palouse River.

Dependable yields of the rivers in the subregion are given in tables 221 to 232. Each table shows the lowest mean flows for from 1 to 10 consecutive years in the 30-year base period and their relationship to the 30-year mean. The difference between any two flows is a measure of the reservoir storage capacity required to make the higher flow available. The lowest minimum-year percentage is that for Palouse River at Hooper, Washington, which has a flow of only 47 percent of the 30-year mean. On the other hand, the Clearwater River at Spalding and the mainstem Snake River have minimum-year flows equal to about 68 percent of the mean. The average minimum-year discharge is about 60 percent of the mean.

Variations in Discharge Long-term variations in discharge and precipitation are presented in figures 411, 412, and 413. The annual means for the base period and for the entire period of record are shown. Although the annual precipitation for a given year varied from the mean by as much as 104 percent, the 5-year moving average varied from the mean by no more than 48 percent.

The 5-year moving averages are presented in order to indicate trends more clearly. Streamflow records are too short and Boise and Lewiston are too sheltered to reveal significant trends, but Spokane precipitation shows the usual general decline from 1895 to 1945, with an increase since then.

The annual variations in streamflow, unlike those for precipitation, are only moderate for some streams and are low for others. The maximum annual discharge of all streams is generally about 2.6 times the minimum annual discharge, ranging from 2.1 for the Snake River to 4.2 for the Palouse River.

Annual variations in flow are confirmed by the slopes of the frequency curves; the Palouse and the upper Salmon and Clearwater Rivers have higher slopes, particularly for the shorter flood periods, indicating wide range from year to year.

Seasonal variations in runoff are clearly shown in the hydrographs of figures 363 to 374. The Salmon River has an almost constant low flow for 7 months, with snowmelt runoff from April to August. The Grande Ronde, Palouse, lower Clearwater, and Snake Rivers have a period of increasing flows earlier in the year.

Seasonal variations are confirmed by the spread of the high- and low-flow frequency curves. The greater spread for high flows in the Palouse and upper Salmon and Clearwater Rivers indicates the greater seasonal range from low to high flows. The long period of low flows in the upper Salmon River Basin is shown by the narrow spread of the curves for periods up to 6 months; it is also shown by the small departure of monthly from annual duration curve.

Streamflow Travel Time Limited time-of-travel studies have been made for the larger tributaries of the Snake River in Subregion 6. They were computed in connection with the routing of flood waves and represent only the higher flows; even the low flows studied are greater than mean annual. Plots of accumulated time in hours versus river mile for various discharges are shown in figures 414 and 415. The times do not conform to expected variations, i.e.: variation inverse to discharge. There are insufficient occurrences well enough documented to clearly define travel times. The examples given merely indicate the best available evidence. The reason for the variations shown probably is variation in location of origin of streamflows; i.e., whether the runoff-producing storm occurred high or low in the watershed. Probably a fairly accurate determination for high flows would result from averaging the curves and the flows shown for each river. Travel times in minutes per mile for the lower 10 miles of all four rivers are summarized as follows:

River	High Flow	Median Flow
Clearwater	54	-
Salmon	15	-
Palouse	8	-
Grande Ronde	5	10

River Profiles Profiles for the lower Snake and Salmon Rivers are shown on figure 416. The profiles were constructed from topographic maps and data from available reports.

(Narrative continued on page 523)

Table 209 - Observed Mean Discharge, in CFS, Salmon River near Challis, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										2019	1048	795	
1929	687	626	578	608	596	589	668	2270	3440	1460	634	558	1060
1930	569	485	618	493	557	520	1750	2840	3670	1490	898	662	1210
1931	847	638	504	552	531	567	940	2310	1830	620	457	439	855
1932	501	477	438	450	479	524	801	3560	5550	2350	886	679	1390
1933	647	639	423	441	395	497	805	1860	6380	1670	736	605	1260
1934	630	672	606	566	597	848	2153	2816	1584	733	494	479	1016
1935	563	605	519	535	503	499	932	2601	4590	1622	677	520	1181
1936	560	567	506	558	575	519	1867	4788	4150	1282	801	611	1399
1937	572	539	508	475	500	524	668	2576	2249	999	474	447	880
1938	501	548	620	519	528	532	1325	4304	6459	2909	1110	798	1682
1939	913	769	664	618	573	712	1444	2828	1701	965	520	502	1021
1940	554	486	520	479	498	625	1478	3989	3144	1062	557	731	1177
1941	853	710	583	593	579	597	963	3895	3122	1241	915	768	1155
1942	719	821	1025	680	636	591	1929	3047	4745	2490	851	687	1520
1943	673	741	663	648	633	680	2720	5211	7080	5566	1874	1061	2303
1944	982	909	725	651	647	618	938	2660	3893	2285	966	718	1333
1945	713	733	567	618	647	585	739	2368	3495	2055	855	638	1169
1946	640	660	602	637	610	653	1852	4329	4279	2012	949	837	1508
1947	993	826	716	562	640	766	1429	5691	4301	2294	1022	795	1676
1948	853	752	643	669	593	591	1040	3797	6556	2066	969	756	1591
1949	824	782	662	616	658	631	1497	4583	3758	1523	803	665	1420
1950	753	778	662	623	664	638	1102	3070	5858	3458	1225	1039	1658
1951	1087	1043	854	717	799	713	2284	5793	5885	3659	1696	1037	2137
1952	1073	909	819	774	705	654	1620	4893	5134	2207	1031	766	1717
1953	714	630	618	746	654	643	1202	2435	5657	3590	1220	865	1583
1954	786	811	692	665	667	651	1467	5081	4357	3082	1154	827	1693
1955	791	723	615	576	544	569	608	2378	4667	2183	908	690	1272
1956	752	805	1011	804	628	817	2155	7102	8405	3274	1412	951	2344
1957	995	883	778	658	736	700	934	5113	6763	2564	996	804	1830
1958	868	724	695	632	688	598	828	6392	5522	2019	1048	795	1740
Mean	754	710	644	605	602	622	1338	3819	4607	2158	938	724	1459

Table 210 - Observed Mean Discharge, in CFS, Salmon River at Salmon, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										2160	1150	936	
1929	1060	1100	868	847	904	1090	1080	2520	3840	1710	783	733	1380
1930	915	870	1070	816	961	910	1990	3050	4060	1690	1080	891	1520
1931	1240	1080	875	940	913	951	1260	2610	2170	747	585	673	1170
1932	867	820	787	800	826	870	1080	4270	6710	2960	979	857	1820
1933	1010	1090	718	756	702	851	1060	2100	7280	2050	898	789	1610
1934	923	1191	1033	974	972	1171	2325	2990	1852	857	596	677	1297
1935	885	944	804	811	799	787	1134	2650	4736	1888	830	688	1413
1936	837	982	819	920	950	910	2181	5023	4751	1499	983	841	1724
1937	861	1034	955	843	900	876	900	2666	2478	1229	550	579	1157
1938	765	801	939	782	790	811	1555	4760	7136	3584	1351	1014	2028
1939	1324	1260	1058	941	877	1080	1757	3162	2124	1225	667	751	1355
1940	906	932	950	862	909	986	1811	4158	3441	1251	665	1096	1497
1941	1368	1167	963	941	915	1001	1213	3089	3614	1591	1280	1154	1527
1942	1201	1285	1527	1117	1100	1063	2717	3851	6335	3171	1096	930	2117
1943	1058	1266	1168	1115	1060	1274	3672	5864	8102	6509	2367	1421	2911
1944	1480	1565	1238	1083	1149	1102	1408	3066	4914	3000	1354	1049	1867
1945	1205	1348	1063	1143	1134	1060	1076	2677	4229	2591	1137	950	1635
1946	1097	1229	1079	1070	1034	1125	2211	4577	4671	2340	1156	1369	1915
1947	1714	1534	1380	1100	1230	1400	2054	6711	5284	2840	1380	1198	2326
1948	1529	1430	1226	1172	1135	1095	1445	4338	7637	2679	1277	1069	2167
1949	1381	1437	1212	1148	1184	1230	1863	5198	4414	1803	1040	953	1908
1950	1260	1324	1196	1019	1180	1096	1448	3254	6793	4118	1545	1458	2142
1951	1559	1694	1428	1175	1271	1251	2855	6610	7089	4215	2145	1364	2727
1952	1602	1496	1315	1262	1202	1165	2230	5725	6091	2682	1328	1026	2261
1953	1211	1278	1147	1335	1154	1106	1519	2742	6956	4222	1490	1109	2107
1954	1159	1399	1271	1188	1179	1126	1674	5258	4764	3579	1378	1087	2094
1955	1147	1239	993	1023	968	993	998	2497	5326	2712	1073	905	1657
1956	1136	1374	1556	1325	1059	1533	2883	7951	9611	3570	1612	1285	2907
1957	1486	1435	1238	1086	1206	1174	1342	6204	8264	3139	1274	1145	2419
1958	1448	1378	1274	1081	1303	1154	1309	7087	6309	2415	1342	1116	2273
Mean	1188	1233	1105	1022	1032	1075	1735	4222	5366	2595	1175	1006	1898

Table 211 - Observed Mean Discharge, in CFS, Salmon River near French Creek, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										9810	4300	3710	
1929	3990	3620	2960	2920	2970	3490	4430	16400	27400	8910	3600	3160	6962
1930	3060	2820	3850	2670	3680	3710	12710	21100	20500	6420	3810	3220	7296
1931	4140	3300	2580	2750	2640	3320	6400	17300	9580	3140	2060	2270	4957
1932	2630	2630	2370	2360	2480	3750	8200	32900	35400	11800	4420	3450	9366
1933	3690	3870	2580	2930	2590	3130	6380	15600	48500	9370	3950	3240	8819
1934	3320	3940	3600	3850	4060	6370	17600	18100	8580	3790	2310	2270	6482
1935	3050	3510	2810	2710	2830	2950	6810	20600	24600	7180	3080	2440	6881
1936	2640	2850	2310	2510	2580	3140	14240	35600	21600	5910	3470	3040	8324
1937	2790	2710	2540	2560	2680	2880	4510	19800	15500	5440	2610	2240	5522
1938	2640	2870	3980	2890	3200	4270	10970	32600	40200	13900	4950	3620	10507
1939	4250	3830	3300	3120	2880	4620	11230	25800	12200	5720	2750	2741	6870
1940	3040	2830	3120	2940	3280	5240	12040	29300	17400	5190	2720	3680	7565
1941	5270	4380	3640	3140	3250	4270	7440	22600	20600	7600	4710	4540	7620
1942	5000	6040	7970	4530	4160	4120	16100	22900	32400	13000	4680	3720	10385
1943	3670	4640	4000	4090	4290	5010	22250	31000	44900	27000	7480	4661	13582
1944	4370	4500	3390	3000	3350	3150	5690	18600	23100	9460	4520	3530	7222
1945	3558	3926	2918	3163	3413	3254	4428	19850	28750	10530	4353	3552	7648
1946	3634	4131	3416	3474	3382	4488	13240	31610	24460	8850	4285	4828	9170
1947	5743	5347	5453	3744	4359	5901	11390	45520	29560	10850	4984	4419	11480
1948	5243	4835	4288	4234	3762	3635	7965	34490	49410	12830	5533	3903	11670
1949	4485	4351	3504	3229	3568	5025	12210	40720	25460	7394	3820	3362	9794
1950	3946	4200	3784	3397	4076	4411	8016	22640	45860	19940	6172	4662	10930
1951	5570	6361	5102	4034	5119	4658	15836	39540	33740	15380	6695	4463	12230
1952	5309	4513	4076	3584	3491	3814	13810	39010	33770	11530	5057	3637	10980
1953	3597	3464	3240	4068	3690	3920	8472	19920	46480	19920	5837	3991	10550
1954	3814	4196	3750	3464	3874	4163	10060	34460	28350	15400	5573	3866	10110
1955	3863	3900	3012	3174	3027	3221	4312	17520	38000	14240	4833	3696	8569
1956	4075	4629	5949	4651	3742	6111	17350	47850	46190	13620	6313	4632	13770
1957	4660	4650	3990	3210	4130	5150	7710	44260	41090	11500	4770	3980	11592
1958	4480	3990	3680	3210	4290	3900	7300	41630	31330	9290	4780	3750	10136
Mean	3984	4028	3705	3320	3495	4169	10303	28640	30164	10837	4471	3619	9233

Table 212 - Modified Mean Discharge, in CFS, Salmon River at Whitebird, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										10990	4810	4120	
1929	4470	4140	3518	3398	3438	4276	5390	19390	32090	9980	4020	3510	8135
1930	3430	3220	4588	3108	4268	4546	15490	24890	23990	7190	4260	3580	8547
1931	4630	3770	3068	3198	3058	4060	7800	20390	11190	3510	2300	2520	5792
1932	2950	3010	2818	2738	2878	4586	9990	38890	41390	13190	4940	3830	10934
1933	4140	4420	3068	3408	2998	3826	7770	18390	56690	10490	4410	3600	10267
1934	3721	4503	4279	4470	4708	7805	21510	21340	10030	4234	2577	2525	7642
1935	3420	4013	3343	3154	3283	3613	8300	24310	28810	8041	3439	2715	8037
1936	2963	3258	2747	2921	2992	3839	17360	42130	25220	6617	3874	3380	9775
1937	3131	3097	3025	2973	3104	3529	5487	23450	18140	6090	2917	2486	6452
1938	2962	3281	4734	3357	3714	5225	13370	38560	47010	15580	5528	4026	12279
1939	4768	4380	3929	3631	3344	5655	13690	30450	14300	6403	3075	3046	8056
1940	3405	3232	3716	3420	3792	6418	14680	34670	20360	5811	3044	4094	8887
1941	5912	5002	4330	3650	3773	5233	9067	26660	24050	8516	5264	5042	8875
1942	5613	6907	9490	5260	4824	5048	19600	27040	37840	14530	5228	4135	12126
1943	4113	5303	4759	4759	4980	6139	27120	36590	52520	30240	8361	5179	15839
1944	4900	5145	4031	3491	3885	3862	6929	22050	27040	10600	5049	3926	8409
1945	3803	4348	3203	3516	3918	4021	5807	24440	34940	12000	4865	4008	9072
1946	4051	4645	4041	4147	3827	5564	15690	35980	27300	10100	4845	5387	10465
1947	6310	6291	6982	4288	4946	7092	13530	51990	32460	11680	5429	4791	12982
1948	5966	5528	4926	5047	4499	4496	10590	42400	60010	14090	6555	4670	14065
1949	5172	5057	4040	3682	4092	6228	14360	47850	28770	8306	4234	3677	11289
1950	4310	4634	4233	3781	4528	5333	9765	24860	50480	21800	6826	5185	12145
1951	6399	7219	5849	4616	5884	5408	18170	44020	37180	16740	7224	4856	13630
1952	5934	5166	4894	4203	4296	4569	16940	43750	39520	13230	5688	4128	12693
1953	3927	3808	3709	4753	4290	4739	10420	23070	53430	22780	6410	4349	12140
1954	4211	4535	4190	3997	4595	5075	11870	39080	32800	16870	5991	4362	11465
1955	4264	4249	3342	3460	3319	3512	5450	20410	43180	16470	5423	4127	9767
1956	4618	5550	7729	5731	4299	7424	20300	56020	52890	14580	6661	4893	15891
1957	5185	5250	4637	3708	4758	6199	9375	51430	47160	12810	5282	4417	13351
1958	4986	4504	4280	3703	4947	4711	8883	48380	35960	10340	5293	4170	11680
Mean	4455	4582	4383	3852	4041	5068	12490	33429	34891	12094	4967	4020	10690

Table 213 - Observed Mean Discharge, in CFS, Grande Ronde River at Rondowa, Oregon

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										1290	569	511	
1929	574	600	530	521	526	2220	2555	4411	4453	1160	419	386	1519
1930	433	413	525	372	2240	2090	3195	2830	2440	720	391	370	1324
1931	496	495	423	600	719	1760	2825	3940	1940	444	269	321	1175
1932	359	441	526	532	709	5185	7511	7820	3920	1590	494	400	2447
1933	475	814	808	798	585	2430	4185	5401	7877	1780	545	520	2174
1934	531	718	1467	2141	1524	2811	3214	2214	1531	597	362	343	1444
1935	475	719	975	850	1058	1331	3728	4245	2899	879	357	323	1476
1936	381	404	343	722	516	2499	6480	6531	2511	567	299	330	1788
1937	343	342	369	283	375	1656	3071	4940	3428	804	319	318	1343
1938	439	600	1174	1059	1108	2675	4404	5135	4221	1371	533	442	1919
1939	525	653	724	596	624	3705	4454	4437	1973	913	386	382	1599
1940	457	441	536	732	2085	3086	3776	3774	2070	573	302	478	1515
1941	751	926	1165	899	1026	1695	2010	3675	4482	1704	575	933	1643
1942	974	1482	2257	1064	1472	2047	5621	5188	4149	2225	614	516	2290
1943	498	853	1605	1697	2349	3349	7798	5393	5833	3949	993	664	2904
1944	603	718	577	457	615	1335	2474	3176	3212	1016	431	422	1242
1945	462	548	448	843	1461	1585	2903	5783	5007	1593	543	494	1795
1946	491	777	1248	1437	1164	3703	5800	7066	4390	2049	648	720	2447
1947	796	1037	3202	1240	2646	2853	3806	5576	3645	1347	545	540	2259
1948	961	1486	1706	2003	1965	2039	5870	9950	9632	2343	846	580	3271
1949	679	755	685	554	1568	4269	5975	8533	3817	1115	501	444	2397
1950	568	725	777	767	2236	3794	4964	5486	6441	2822	792	534	2481
1951	786	1033	1371	1405	2988	2519	5530	5594	3197	1329	537	493	2221
1952	803	848	901	656	1108	2081	5937	7384	4833	2117	697	585	2319
1953	475	479	484	1715	2564	2525	4179	5921	7129	3440	942	571	2525
1954	543	678	1020	1030	1734	1690	3596	4398	3686	1788	723	613	1781
1955	557	577	489	496	539	804	3101	5067	5526	2082	490	505	1675
1956	657	1112	2722	2486	1401	3984	7315	8904	5822	2042	741	616	3139
1957	616	694	1387	704	1667	4053	5093	8711	4789	1440	615	511	2513
1958	698	666	1391	1177	3924	2140	5332	8369	6082	1439	618	548	2699
Mean	580	734	1061	994	1483	2597	4557	5662	4363	1575	551	497	2044

Table 214 - Observed Mean Discharge, in CFS, Selway River near Lowell, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										3030	1025	740	
1929	1055	760	645	515	565	1490	3075	11480	11280	2380	720	495	2872
1930	520	513	867	462	1580	1720	8360	9710	6470	1500	627	582	2740
1931	1050	897	715	820	835	1620	4470	11600	4460	958	484	531	2380
1932	503	644	672	641	899	2460	6720	16700	12700	2870	789	588	3850
1933	684	1340	986	899	687	1330	5160	10400	21600	3280	823	614	3970
1934	1639	2485	3838	3710	2929	6240	13210	10170	3090	918	441	403	4092
1935	679	1338	1045	920	1064	1495	4944	12220	9199	1984	630	438	3002
1936	454	480	457	629	560	1623	11550	18760	6186	1297	597	518	3598
1937	446	399	480	325	420	904	2305	11970	7745	1549	599	404	2306
1938	446	585	1021	921	896	1747	7100	14130	10690	2056	738	481	3407
1939	633	767	1065	863	774	2416	7744	15050	5460	1820	606	481	3154
1940	565	556	939	991	1264	2602	6692	12460	5326	1044	463	600	2795
1941	924	868	1001	861	862	1480	3706	8018	5191	1710	761	1353	2233
1942	1980	2598	2756	1526	1125	1509	7737	8926	8587	2675	807	591	3404
1943	558	1376	1544	1601	1514	2498	11490	13160	16150	6756	1208	680	4877
1944	621	792	608	464	620	827	3030	10220	7126	1884	775	563	2297
1945	521	596	538	935	1020	1083	2836	13560	10720	2584	728	702	2994
1946	835	1606	1355	1359	1136	2815	8046	14230	8695	2792	968	989	3745
1947	2214	2178	4451	1664	2252	3086	7033	20720	10440	3123	937	782	4926
1948	1474	1795	1835	2020	1599	1570	5729	19570	17670	3242	1395	778	4890
1949	797	1016	809	635	933	2570	8920	22430	10910	2359	777	584	4413
1950	853	1619	1593	1406	2062	2914	6483	12630	19290	6440	1491	791	4796
1951	1645	2330	2241	1687	2923	1790	7818	15440	10620	3646	951	627	4311
1952	1251	1093	1002	768	1011	1402	9220	17130	10160	2385	824	519	3898
1953	417	414	456	1132	1446	1438	4305	10210	16400	4782	920	509	3532
1954	463	592	770	708	1269	1583	5824	15970	11990	5084	1124	701	3851
1955	708	762	707	689	668	692	2580	11830	18860	6268	1256	735	3818
1956	965	1785	2709	1892	1183	2543	9889	19960	11660	2672	976	669	4748
1957	773	982	1304	775	1198	2369	4747	18820	12380	2441	797	526	3940
1958	625	595	734	648	1479	1400	4235	17950	8216	1914	778	667	3283
Mean	877	1125	1305	1082	1226	1974	6499	14181	10642	2814	833	630	3604

Table 215 - Observed Mean Discharge, in CFS, Lochsa River near Lowell, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										1870	635	455	
1929	650	465	395	320	345	920	1895	7080	6955	1470	440	305	1770
1930	386	345	873	391	1470	1580	6960	6820	4150	1080	476	469	2080
1931	787	833	605	633	726	1760	4310	9030	2980	734	348	369	1930
1932	377	511	475	464	692	2170	5750	13200	8520	1910	594	435	2930
1933	573	1320	796	778	558	1190	4210	8360	16400	2290	628	528	3130
1934	1657	2454	4844	4245	2697	5250	10750	7353	2432	747	358	326	3596
1935	606	1145	833	776	873	1419	4080	9205	6005	1355	478	326	2263
1936	363	360	359	491	414	1176	8295	13080	4204	913	399	367	2538
1937	332	294	354	251	325	677	1946	9073	5470	1130	459	310	1724
1938	343	517	886	322	723	1523	5989	10810	7270	1514	527	351	2612
1939	474	581	827	663	565	1669	5926	10240	3508	1204	407	319	2208
1940	417	401	854	913	1245	2442	5802	8680	3579	734	326	386	2149
1941	563	641	829	665	638	1203	2738	5293	3487	1186	542	1156	1581
1942	1553	1993	2492	1210	854	1068	5209	5903	5339	1799	567	398	2368
1943	385	1112	1138	1148	1012	1733	8382	10660	12310	4831	861	460	3671
1944	449	530	487	371	501	693	2472	6816	4684	1342	550	455	1614
1945	423	538	499	1111	970	1037	2590	10970	6875	1684	515	526	2319
1946	587	1280	1151	1183	891	2119	6322	10310	5474	1874	641	589	2709
1947	1423	1735	3919	1564	1959	2426	5537	13840	7213	2032	674	595	3587
1948	1233	1407	1426	1771	1357	1419	5074	15500	12120	2141	931	501	3742
1949	553	764	601	530	738	1814	6267	16630	7310	1658	561	455	3170
1950	673	1196	1226	1150	1533	2411	5115	10020	14950	4709	1210	598	3732
1951	1467	2316	2306	1777	2548	1584	6237	11570	7488	2649	684	466	3424
1952	1104	939	917	645	762	1057	6687	12240	6490	1686	573	365	2791
1953	287	289	330	1006	1356	1241	3401	7748	10920	3035	667	374	2551
1954	316	466	635	611	1049	1298	4797	13080	9753	3995	977	621	3142
1955	587	680	621	551	564	597	2124	9089	13610	4082	875	534	2829
1956	725	1322	2272	1526	959	1711	7361	15110	8830	2165	715	462	3602
1957	590	881	1237	674	969	1963	4239	14800	8742	1738	587	388	3079
1958	489	458	583	548	1249	1177	4035	13700	5578	1382	542	498	2529
Mean	679	926	1159	960	1018	1611	5150	10540	7421	1969	604	463	2712

Table 216 - Observed Mean Discharge, in CFS, Clearwater River at Kamiah, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										6100	2120	1550	
1929	2150	1600	1340	1110	1160	3340	7110	24200	23300	4840	1460	1020	6070
1930	1139	1110	2040	1040	3680	3850	19700	18900	13500	3160	1310	1360	5880
1931	2190	2020	1550	1730	1900	3990	11100	25400	8330	1940	977	1060	5200
1932	1220	1360	1350	1250	1820	6560	16300	41100	24300	5240	1630	1220	8640
1933	1480	3090	2200	2170	1540	3560	12200	23100	49200	6340	1610	1410	8970
1934	3243	5186	9300	9357	6815	13780	27620	19000	6395	1924	853	806	8691
1935	1583	2805	2192	1997	2312	3836	11050	24570	17060	3986	1339	946	6151
1936	1082	1102	1018	1445	1262	4497	24210	36550	12200	2692	1174	1030	7365
1937	955	857	1083	743	959	2107	6038	24630	15270	3329	1257	860	4862
1938	968	1389	2355	2020	2095	4742	16660	29280	20260	4212	1521	1050	7227
1939	1434	1746	2177	1882	1663	5493	16300	28100	10280	3587	1170	950	6258
1940	1196	1149	2026	2336	3523	6775	15790	23370	9831	2028	903	1169	5842
1941	1892	1958	2272	1850	1893	3319	7958	15470	12050	3757	1630	2916	4755
1942	4236	5687	6328	3346	2972	3733	16690	19470	17090	5740	1687	1252	7358
1943	1188	3016	3380	3432	3598	5781	24900	28210	32330	13130	2497	1458	10240
1944	1355	1672	1386	1074	1441	2145	7872	19990	14190	4189	1637	1236	4852
1945	1162	1422	1234	2568	2720	3002	7327	29080	21110	5300	1502	1577	6516
1946	1694	3429	2875	3184	2549	6528	17840	28050	15970	5487	1875	1910	7634
1947	3987	4578	10110	4100	5408	7239	15990	39070	20050	6003	1937	1711	10050
1948	3205	4095	4424	5097	3893	4625	15060	45220	36910	6973	2932	1605	11170
1949	1676	2229	1757	1528	2443	6932	19380	45460	20160	4671	1586	1300	9129
1950	1885	3337	3424	3026	4835	7454	14890	27140	38890	12520	3234	1620	10180
1951	3469	5518	5609	4222	6828	4733	17340	31520	20280	6959	1885	1246	9131
1952	2690	2384	2376	1779	2373	3398	19550	36210	19730	4980	1692	1121	8194
1953	917	918	1027	2870	3836	3600	9986	22230	32220	8824	1850	1071	7436
1954	1021	1391	1804	1629	3003	3599	12910	32460	25080	10240	2551	1613	8126
1955	1587	1788	1492	1484	1555	1623	6887	25830	37460	12780	2640	1551	8067
1956	2036	3994	6441	4729	2775	6736	22170	40950	23780	5919	2040	1397	10260
1957	1727	2321	3115	1808	3046	6766	12510	42730	25170	5158	1714	1197	8972
1958	1455	1417	1735	1557	3536	3234	11670	35560	16200	4080	1662	1507	6989
Mean	1861	2486	2981	2545	2914	4899	14834	29428	21286	5666	1725	1340	7674

Table 217. Modified Mean Discharge, in CFS, Clearwater River at Spalding, Idaho

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										10000	4360	5820	
1929	7571	8877	3590	3468	5699	10076	15200	27855	25600	8190	3700	3792	10302
1930	5741	7667	5250	12119	9670	11729	28557	22690	15900	5511	3550	3440	10985
1931	4410	4200	9680	13471	9375	12100	25006	26250	11000	4250	3104	3200	10504
1932	3270	3590	3701	11235	4350	20600	33782	46839	34990	9350	3968	4420	15008
1933	6471	12867	6000	13655	10758	14839	23300	30865	58223	11700	4180	5070	16494
1934	10684	17274	33250	28480	15940	34532	37670	30582	10760	4307	3108	2965	19129
1935	6726	11528	5954	8110	9713	11276	19330	29959	27540	7119	3601	3689	12045
1936	5673	7828	3203	13036	12331	12806	35173	47052	20650	5091	3380	3660	14157
1937	5389	7410	3238	10671	7536	7701	19108	28720	17837	5603	3522	3005	9978
1938	3120	3588	5112	13885	11421	11485	25940	36342	30940	7386	3763	3982	13080
1939	6278	9115	5289	4904	7697	14424	24367	35885	16370	6105	3349	3484	11439
1940	5772	7916	5548	6144	14120	16633	23428	30236	14842	7162	4646	3287	11644
1941	4384	8398	7847	7152	9065	7633	11136	18325	24540	9256	4764	5415	9826
1942	6682	8590	12701	7465	9406	8592	20990	24215	24216	9488	4010	4362	11726
1943	5770	12195	8382	15435	14469	20818	44036	38255	43003	20910	5285	4811	19447
1944	6397	9142	4575	3966	5669	9807	17258	23355	21487	10465	4376	3630	10010
1945	3275	3589	4036	14440	9987	8773	17131	35820	29492	7769	3616	3926	11821
1946	5418	6044	10593	13289	11026	13192	25600	35888	25703	9723	4204	5443	13844
1947	10051	14538	23982	16625	15429	17637	25264	47826	30640	9633	4278	5258	18430
1948	10070	14989	10757	18660	14628	24320	34390	63319	54023	12420	5890	5899	22447
1949	6920	10688	5148	13223	15590	22308	31347	54186	30280	8335	3920	4460	17200
1950	6975	11382	6931	14459	15016	28860	34910	36954	47690	21800	6780	5381	19762
1951	10193	16781	13865	13148	15755	22147	27710	40599	30420	10860	4178	4598	17521
1952	9500	11162	7012	11933	9970	10955	31676	46469	30030	9148	3976	4323	15513
1953	5354	7568	3090	15284	13279	7892	18855	29127	42187	13480	4363	4173	13721
1954	5577	8732	5595	13369	11702	19268	22727	40272	31550	17420	5161	5114	15540
1955	7873	9683	4303	10614	9543	6840	18330	31594	45090	20150	5502	5138	14555
1956	8093	15057	17749	16146	9546	32094	42374	50180	33287	10890	4860	5002	20440
1957	7119	10556	8100	13107	14955	16381	23480	53145	35037	8542	4138	4247	16567
1958	6515	8742	5284	12477	14019	9597	23434	42808	25630	10000	4360	5820	14057
Mean	6576	9656	8326	12332	11255	15510	26050	36854	29632	10069	4251	4366	14573

Table 218. Modified Mean Discharge, in CFS, Snake River near Clarkston, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										33880	19370	20340	
1929	24161	29983	23036	29079	32628	49170	41594	64281	66370	22092	17280	19192	34906
1930	22271	24743	26556	39602	37546	40129	58774	52280	45080	15692	18180	19224	33340
1931	21420	20717	28146	44315	38584	41101	54316	56661	26724	11689	14464	16340	31206
1932	17490	19610	23336	38827	22011	56330	62266	98389	85330	27479	13369	20567	40417
1933	23972	32919	26115	33074	41485	49422	50836	74135	127683	27787	15558	20840	43652
1934	26156	36747	50415	51690	54266	59449	72020	67868	28338	14564	11874	11526	40409
1935	21415	28615	25486	28047	39804	35274	41400	68616	66887	21813	12602	12264	33519
1936	20667	25501	21247	36411	46538	52324	69262	99712	60002	21530	17936	19580	40892
1937	21967	25719	21899	38027	35526	38636	52872	60960	42967	14946	8998	17910	31702
1938	17831	16779	27063	39574	55031	67187	78664	86112	89419	39620	20327	19120	46394
1939	24737	29789	27264	29739	37238	58292	57128	84715	35930	15812	14847	19370	36238
1940	22756	25929	25803	31644	53532	65354	59646	88102	41632	17032	18086	19514	39086
1941	22429	28990	30633	33724	44120	46565	32915	64145	65849	30318	22922	20332	36912
1942	17945	26613	45508	37539	55350	52517	61436	84585	69796	29100	12263	21292	42829
1943	23270	33555	33438	47140	72363	91329	118356	147284	107773	58900	16960	20534	64242
1944	26004	30850	25942	29005	38310	44907	46119	53538	74862	33817	20020	19758	36928
1945	19059	21687	24398	41937	38953	38861	48112	80065	77452	24449	17750	25163	38157
1946	26994	21952	28710	40667	59296	83634	85644	86328	67214	32750	19290	24210	48057
1947	32161	39943	59204	42335	67345	75321	59530	113276	79363	32468	20125	22646	53643
1948	31064	39429	36333	45735	64013	74056	82566	129919	144877	44480	23400	23460	61611
1949	28141	32793	27976	39858	64052	87670	74367	121326	73747	28200	19104	20690	51494
1950	26446	31016	28326	38294	68766	91346	89560	95484	114620	52340	18561	23670	56536
1951	35688	43921	41485	39192	86172	88017	98117	96979	78400	40779	22880	21580	57768
1952	32986	34467	36573	40790	64003	81912	92336	157790	110290	42600	21518	22416	61473
1953	24721	27505	24618	49577	65433	61803	61442	87657	113397	44610	19627	22100	50208
1954	25441	29843	29036	36562	62758	71447	54172	91882	76742	48512	22330	22192	47576
1955	27226	29871	24939	32838	43398	35202	40708	73119	104847	44869	16602	20410	41169
1956	26011	35757	52501	46071	62654	107734	98098	134565	133957	40530	24100	23890	65489
1957	29481	33893	33773	36744	66305	83093	81980	126265	121073	34280	21994	22366	57604
1958	28856	30572	30102	37103	72233	69155	84814	110588	87519	33880	19370	20340	52044
Mean	24959	29657	31329	38505	52990	63241	66968	91888	80605	31565	18078	20417	45850

Table 219 - Observed Mean Discharge, in CFS, Palouse River at Hooper, Washington

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										61	10	13	
1929	53	90	176	497	683	1210	617	198	147	55	5	8	312
1930	27	82	174	465	1720	565	900	135	93	47	5	10	352
1931	32	67	113	461	1610	1060	633	139	62	39	0	2	352
1932	16	47	106	405	706	1970	1230	561	183	63	8	12	442
1933	27	102	131	532	1610	887	800	203	340	55	10	13	393
1934	40	138	127	2390	1500	1750	1300	115	58	42	2	3	622
1935	21	73	323	1230	894	1130	1500	484	123	50	3	7	486
1936	16	43	102	474	688	1190	1680	519	120	47	5	12	408
1937	19	40	103	342	662	968	567	213	97	47	3	7	256
1938	19	60	169	608	998	1610	1470	485	213	74	10	13	477
1939	37	78	137	537	846	1660	1080	253	73	48	5	10	397
1940	26	50	124	569	1900	1400	1220	258	88	48	3	15	475
1941	47	90	169	615	1520	774	517	147	113	53	11	35	341
1942	68	188	887	750	1250	1110	1330	229	157	66	11	18	505
1943	34	122	252	1230	2000	1970	2550	424	322	132	37	27	758
1944	61	113	144	505	805	968	600	137	125	55	10	15	295
1945	31	73	111	640	1280	1100	567	342	183	61	11	20	368
1946	42	142	294	1100	2680	1610	1650	423	142	60	13	33	682
1947	92	222	2550	952	2190	1520	967	582	170	61	15	28	779
1948	89	183	355	1610	3130	1450	1330	1770	667	290	32	30	911
1949	52	100	161	647	1560	2370	1380	710	140	55	11	20	600
1950	55	110	160	666	1800	1950	1320	344	327	115	45	35	577
1951	105	277	629	1270	3710	1845	1104	431	252	72	22	27	812
1952	117	158	345	329	2791	2634	2345	715	198	135	53	41	813
1953	45	64	118	1960	2029	1291	790	736	376	85	36	30	622
1954	46	99	392	675	1809	1135	970	417	254	81	37	60	489
1955	72	120	153	513	754	896	1528	898	226	81	17	21	437
1956	93	349	2101	2145	1181	3488	2051	961	282	94	35	38	1072
1957	76	119	283	146	1469	2191	1451	1335	319	72	31	20	621
1958	61	89	311	862	2687	1036	2042	648	174	64	13	18	651
Mean	51	116	373	838	1615	1491	1250	494	201	75	17	21	543

Table 220 - Modified Mean Discharge, in CFS, Snake River below Ice Harbor Dam

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1928										30500	17290	18600	
1929	23431	30393	23206	29409	34258	50940	41094	61361	62640	21822	16430	18262	34437
1930	21751	24643	26926	39242	40456	40229	55404	49370	42130	14452	17050	18044	32475
1931	21570	20907	28686	44875	39154	41381	55586	53641	25674	11509	13704	15660	31029
1932	18100	20560	24152	40057	22091	58860	62596	96189	84240	30239	14159	21637	41073
1933	24512	33849	27105	35144	42855	50982	50486	72895	126083	28977	17458	21970	44360
1934	26196	38297	51335	54860	56826	59739	69565	66708	28908	16054	12884	12206	41132
1935	21475	29285	26626	28677	41244	36234	40860	65706	65477	22553	14372	13024	33794
1936	21127	26241	21977	37511	47888	53874	65622	97312	60192	23460	19026	20460	41224
1937	22277	26409	22389	38017	36986	39636	52792	58440	42047	17646	10578	18680	32158
1938	18351	17429	28943	41244	56621	68697	76470	83912	91719	42610	22207	19760	47330
1939	25767	30669	27674	29989	37868	58382	56328	82475	37090	17882	16567	20360	36754
1940	22836	27229	26323	32424	53532	66544	58546	85832	42362	18932	19726	20434	39560
1941	23389	31480	32073	35504	45860	47675	33455	63255	67599	31701	23582	21512	38090
1942	19275	28433	47338	39609	58120	53847	61346	83115	70736	30820	14293	23122	44171
1943	23600	34415	35028	49020	74583	91499	114936	143284	103173	58250	18790	21084	63974
1944	25614	31350	26062	28715	38690	44917	45089	50568	72292	33957	19390	19188	36319
1945	18999	22167	24328	42447	39433	39221	47792	75465	75252	26029	18110	25123	37864
1946	26964	22412	28950	43107	59986	84614	83704	83628	68014	34180	20240	24630	48369
1947	32341	40103	60104	43275	68165	75231	57430	108976	78923	33618	21405	22626	53516
1948	30214	40499	37393	47045	65343	75236	80302	122119	150477	46940	23250	23970	61899
1949	28351	33393	28226	39528	66432	89070	70717	117026	75427	27950	19254	20740	51343
1950	26406	30596	29196	38984	71134	93096	88295	89984	112120	55550	19341	23950	56554
1951	35188	44871	41975	41962	87542	90107	95967	90779	77230	39839	23250	22190	57575
1952	32806	34997	37193	41580	66343	82402	90336	151890	108290	42500	21658	22166	61013
1953	24371	27875	24888	50927	67383	62643	58672	83917	109397	43500	19997	21680	49604
1954	23181	30363	30146	38382	65158	72907	54812	87182	74702	47002	22400	22762	47416
1955	27136	30991	25309	33708	43908	35732	40018	72089	97047	42079	15912	19960	40324
1956	26071	36707	54521	49041	64364	110224	97438	131765	137857	40910	23900	23980	66398
1957	30191	35413	34623	36844	67235	85893	82560	123365	122573	34460	20874	22316	58029
1958	29016	31442	31232	38383	74463	70285	85628	106288	87719	30500	17290	18600	51737
Mean	25017	30447	32131	39650	54464	54337	65796	88618	79913	32197	18570	20670	45984

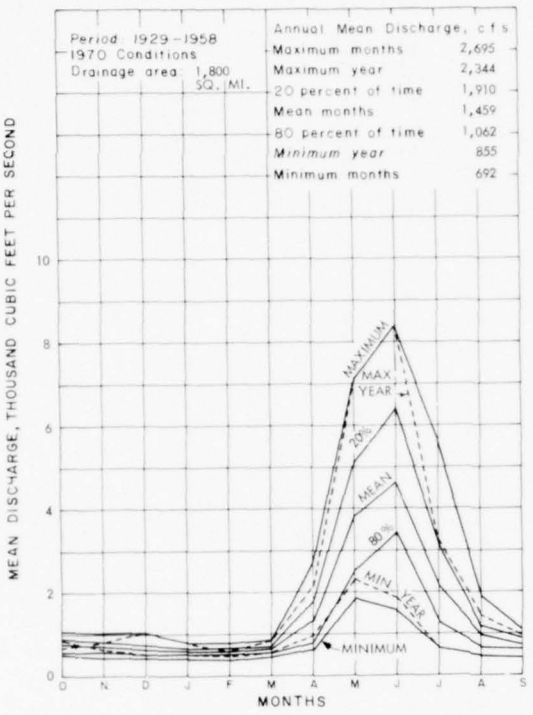


Figure 363 Monthly discharge, Salmon River near Challis, Idaho

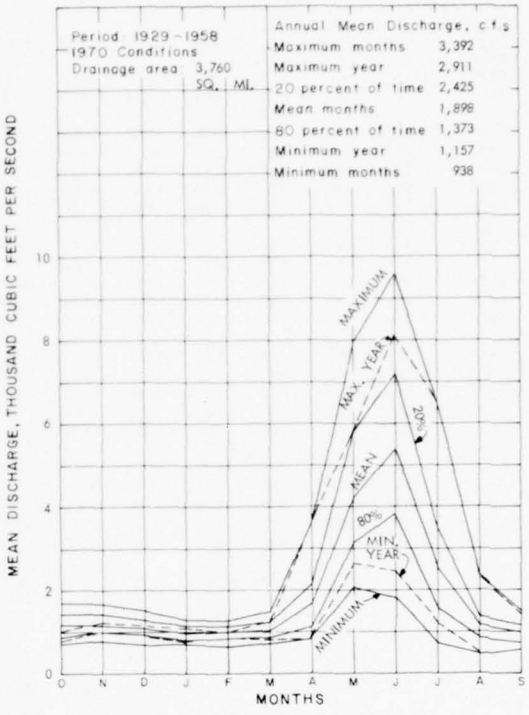


Figure 364 Monthly discharge, Salmon River at Salmon, Idaho

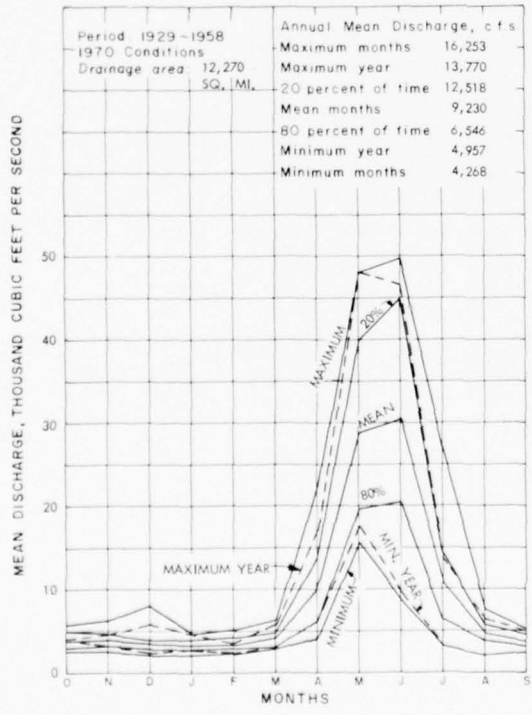


Figure 365 Monthly discharge, Salmon River near French Creek, Idaho

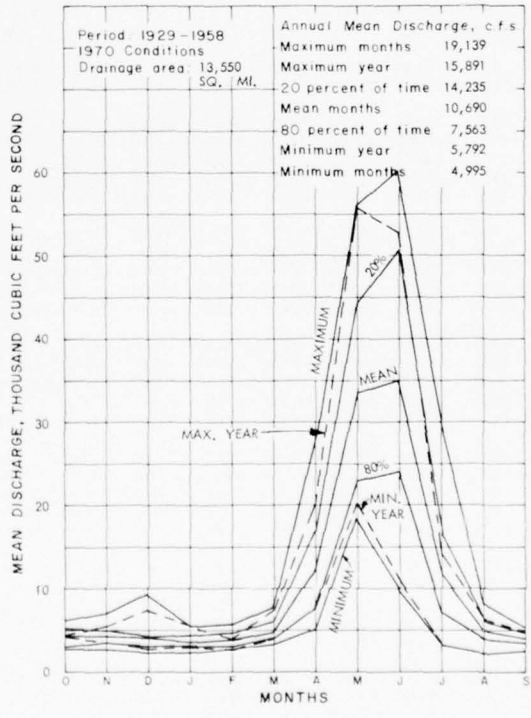


Figure 366 Monthly discharge, Salmon River at Whitebird, Idaho

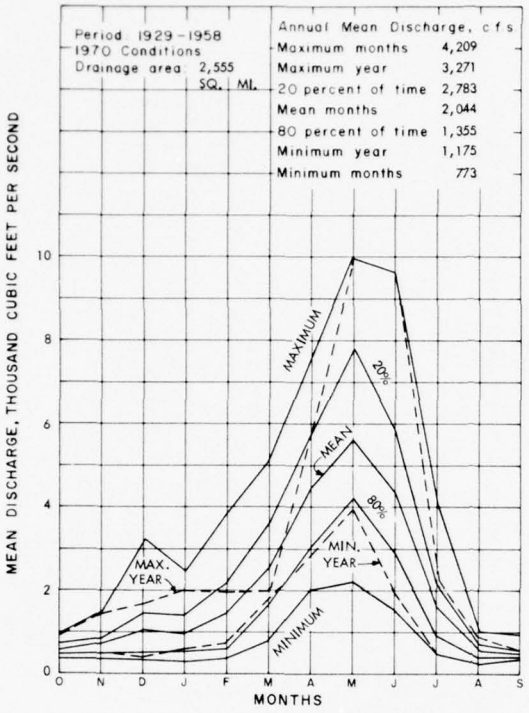


Figure 367 Monthly discharge, Grande Ronde River at Rondowa, Oregon

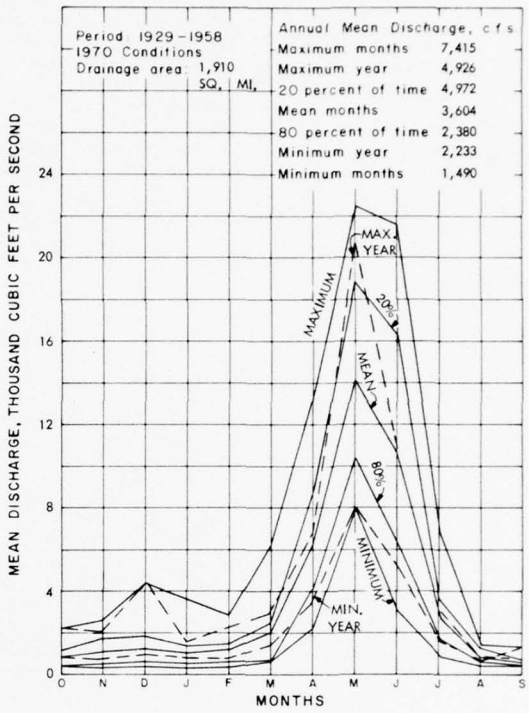


Figure 368 Monthly discharge, Selway River near Lowell, Idaho

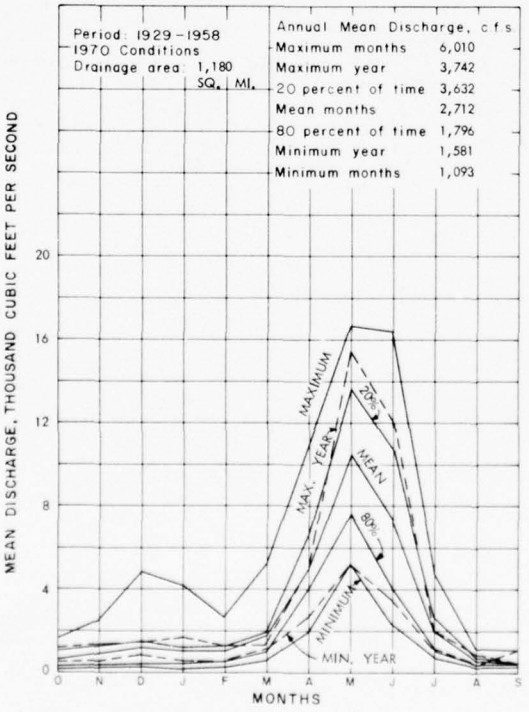


Figure 369 Monthly discharge, Lochsa River near Lowell, Idaho

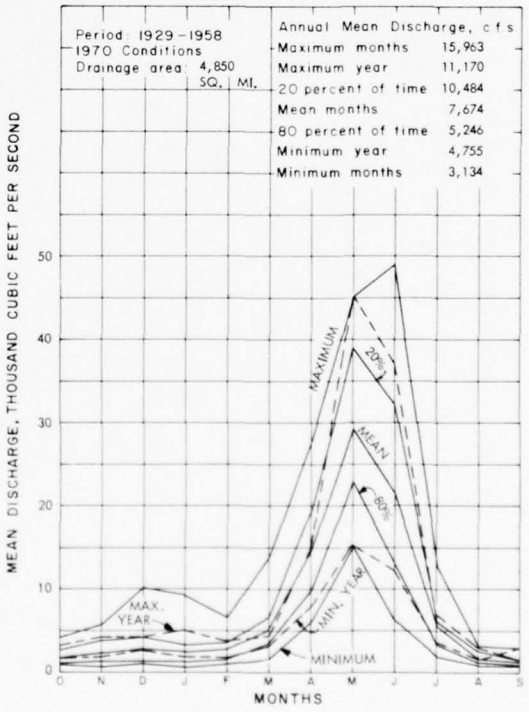


Figure 370 Monthly discharge, Clearwater River at Kamiah, Idaho

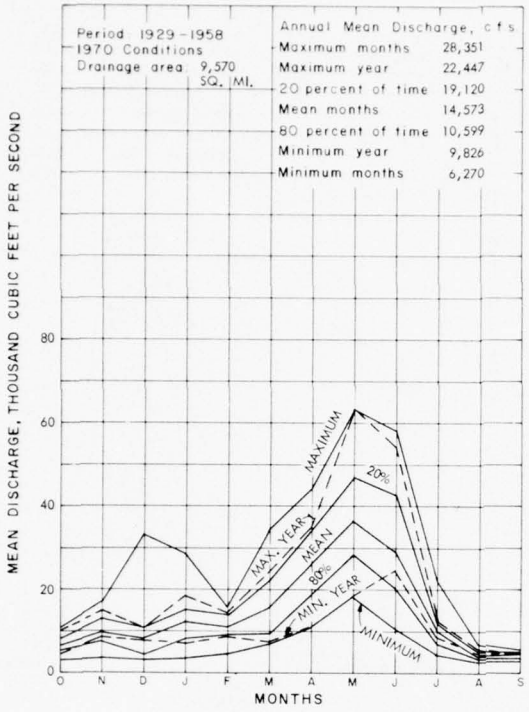


Figure 371 Monthly discharge, Clearwater River at Spalding, Idaho

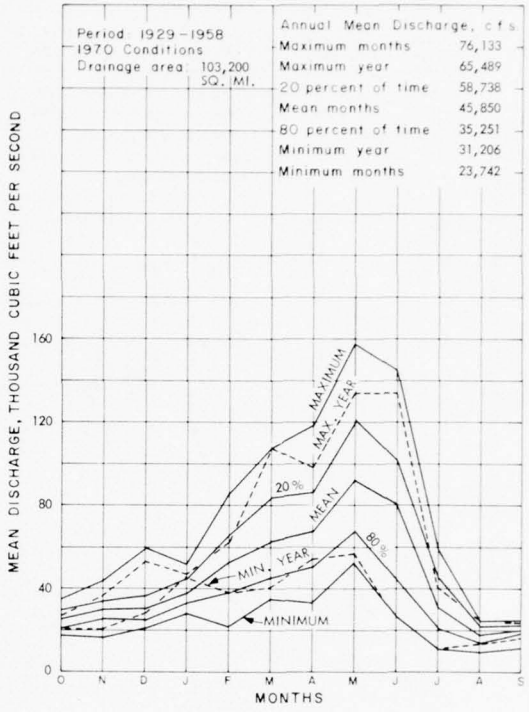


Figure 372 Monthly discharge, Snake River near Clarkston, Washington

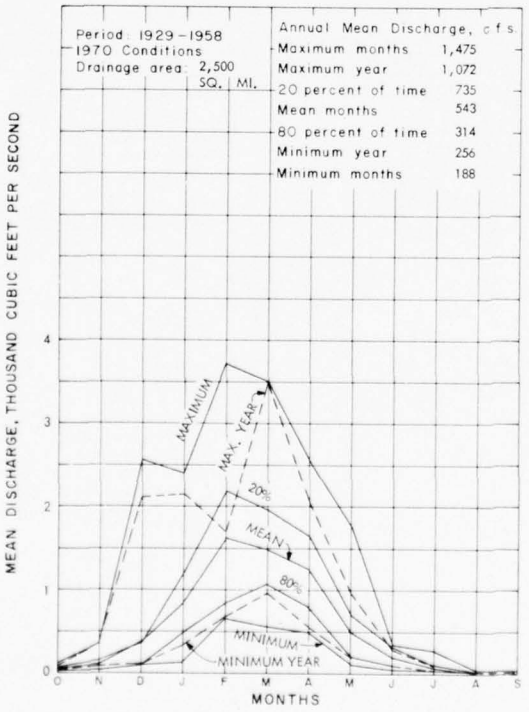


Figure 373 Monthly discharge, Palouse River at Hooper, Washington

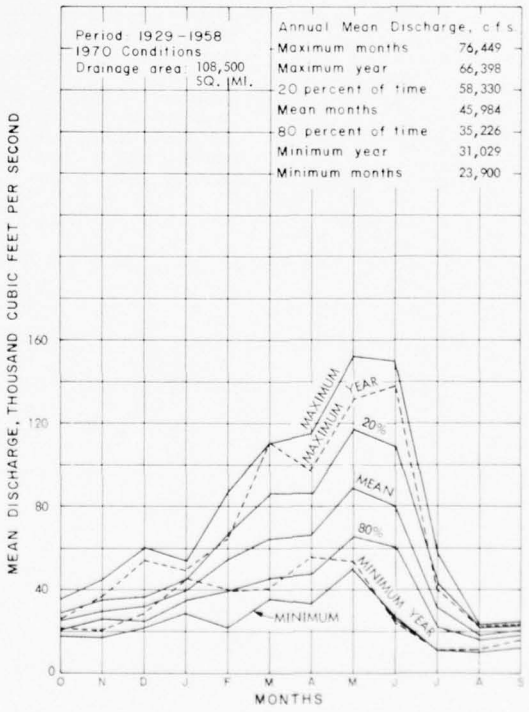


Figure 374 Monthly discharge, Snake River below Ice Harbor Dam, Washington 1929 - 1958

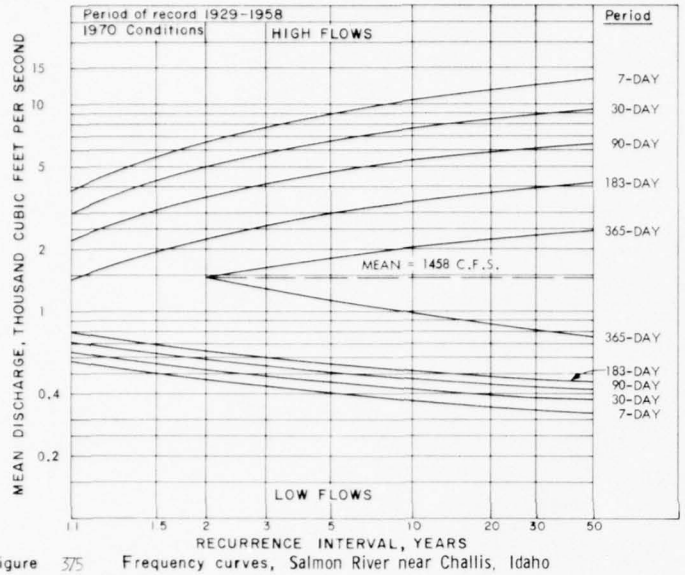


Figure 375 Frequency curves, Salmon River near Challis, Idaho

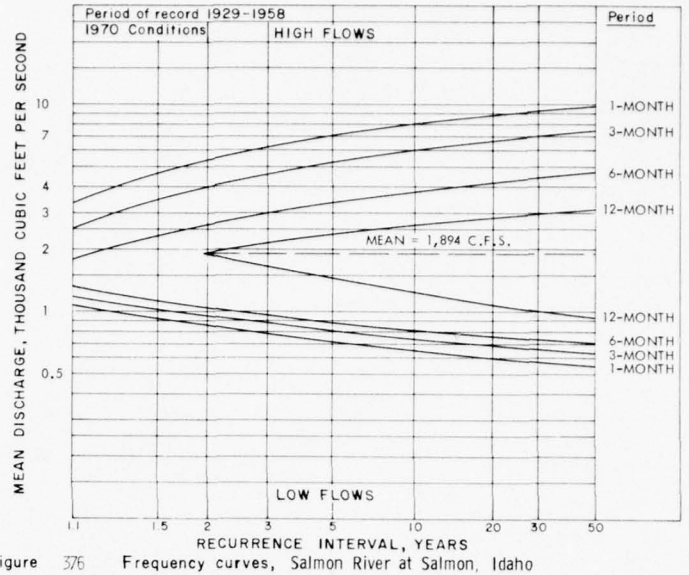


Figure 376 Frequency curves, Salmon River at Salmon, Idaho

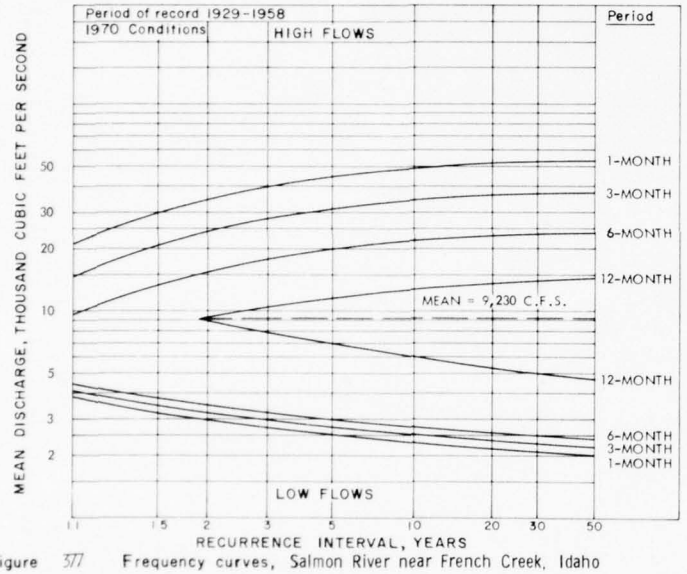


Figure 377 Frequency curves, Salmon River near French Creek, Idaho

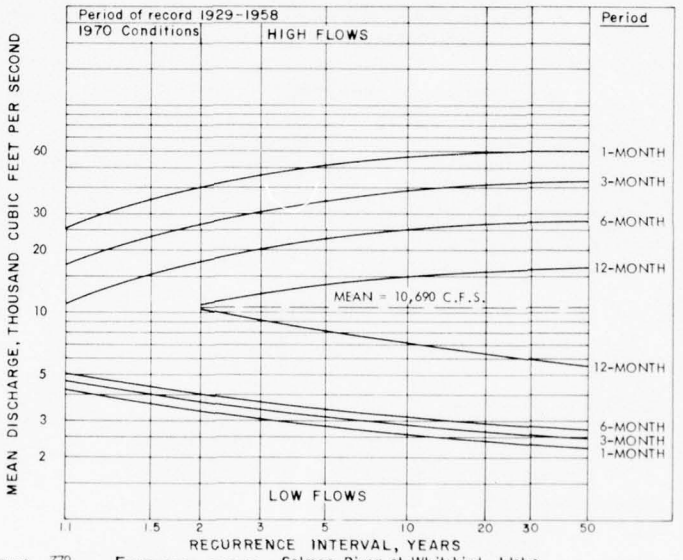


Figure 378 Frequency curves, Salmon River at Whitebird, Idaho

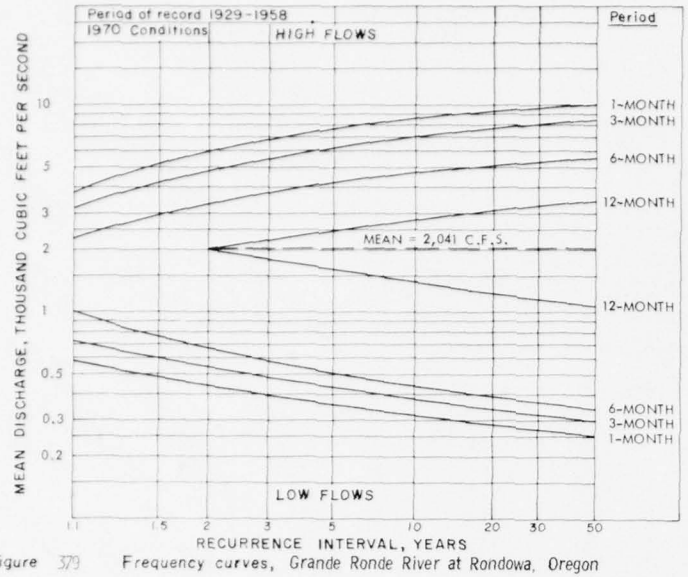


Figure 379 Frequency curves, Grande Ronde River at Rondowa, Oregon

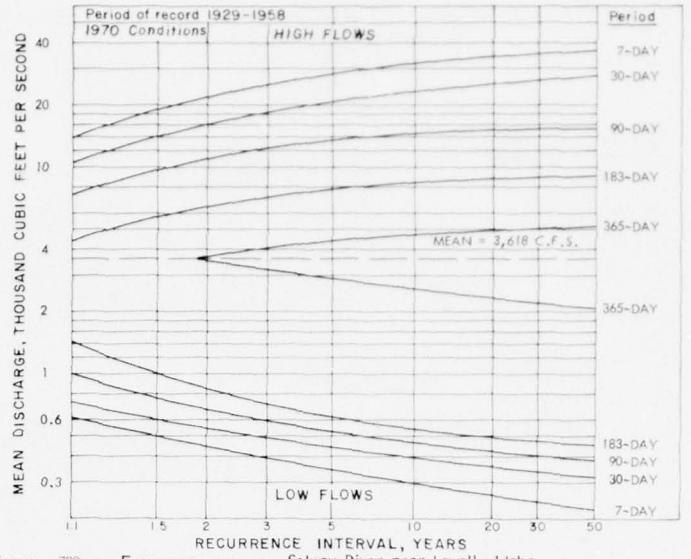


Figure 380 Frequency curves, Selway River near Lowell, Idaho

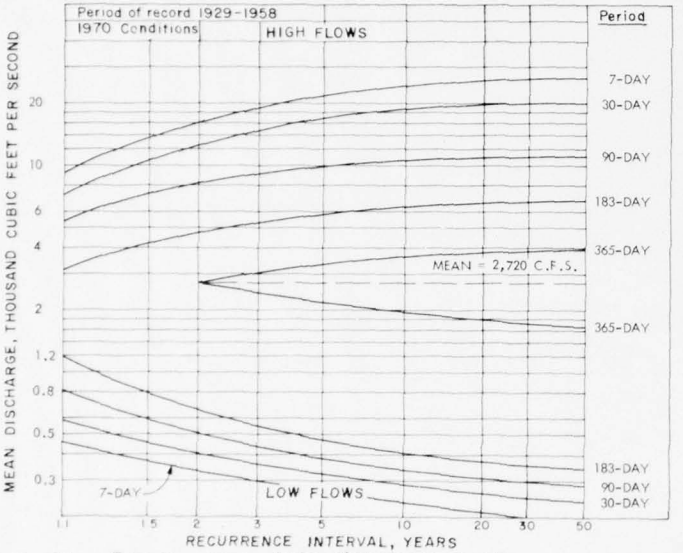


Figure 381 Frequency curves, Lochsa River near Lowell, Idaho

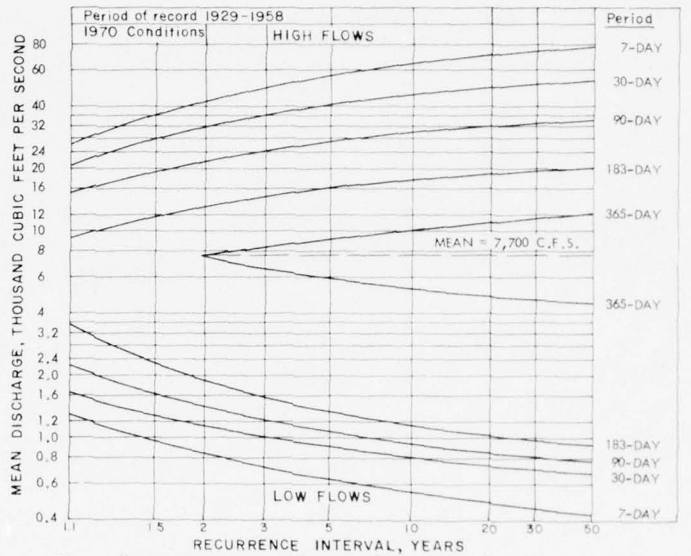


Figure 382 Frequency curves, Clearwater River at Kamiah, Idaho

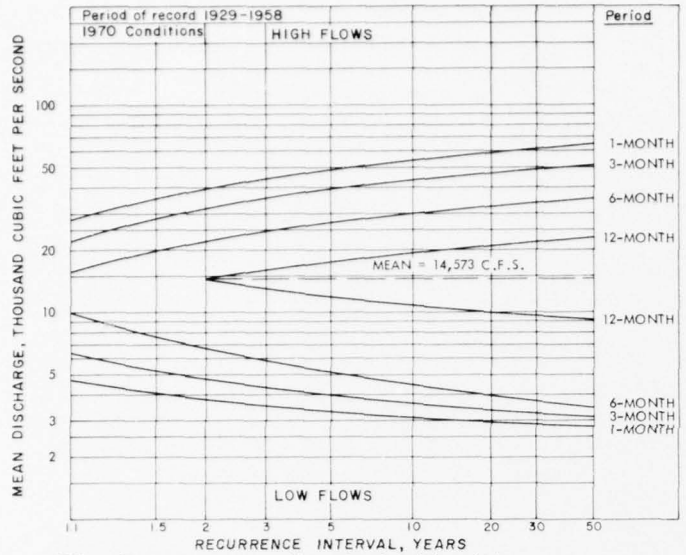


Figure 383 Frequency curves, Clearwater at Spalding, Idaho

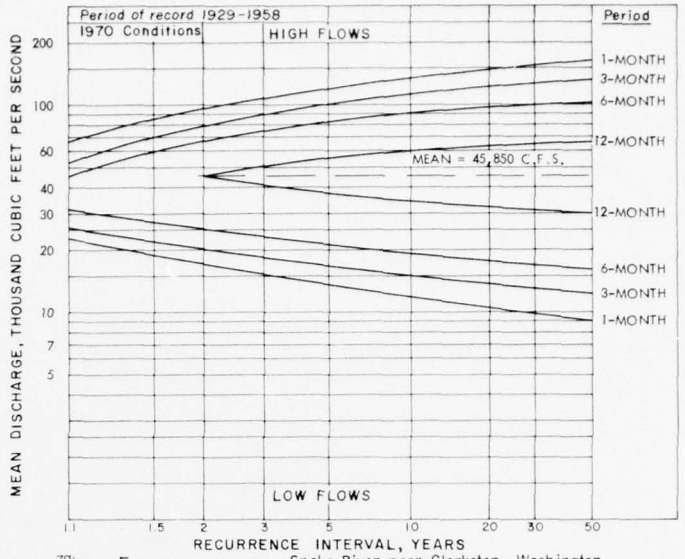


Figure 384 Frequency curves, Snake River near Clarkston, Washington

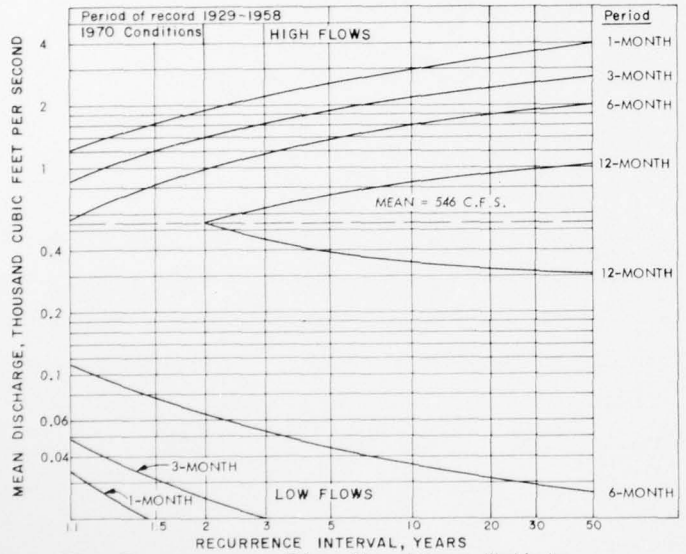


Figure 385 Frequency curves, Palouse River at Hooper, Washington

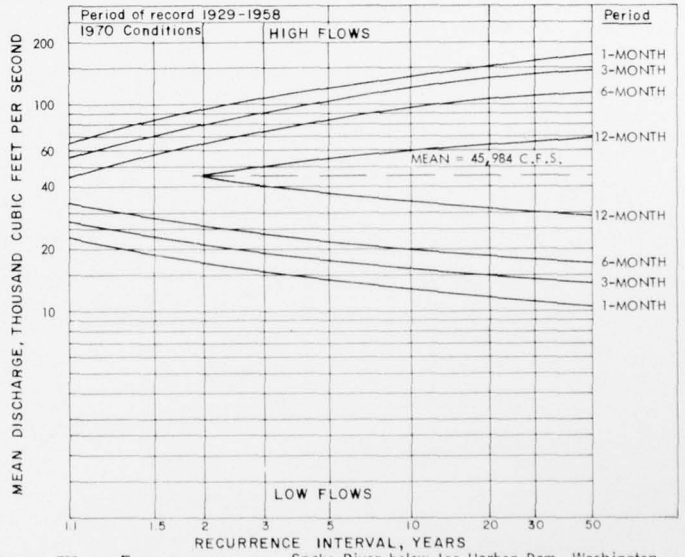


Figure 386 Frequency curves, Snake River below Ice Harbor Dam, Washington

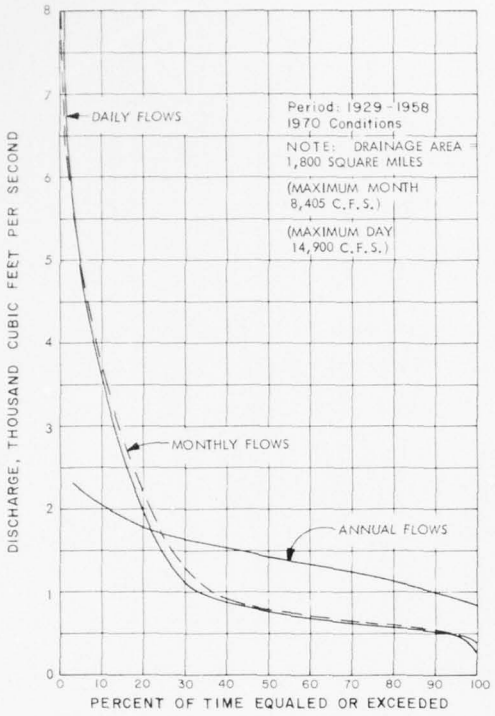


Figure 387 Duration curves, Salmon River near Challis, Idaho

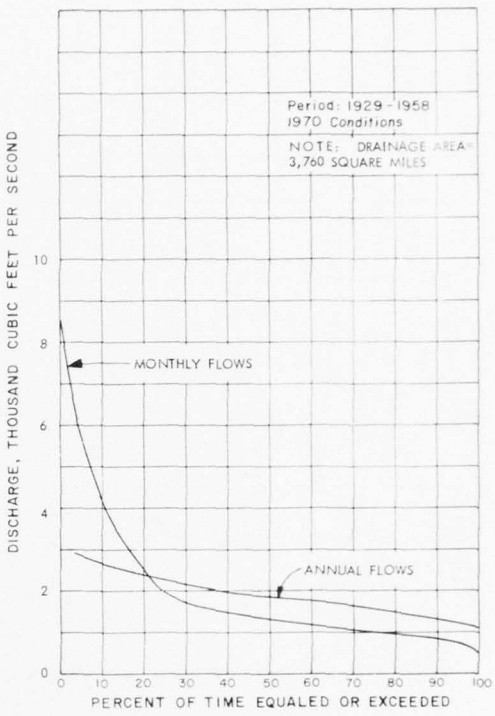


Figure 388 Duration curves, Salmon River at Salmon, Idaho

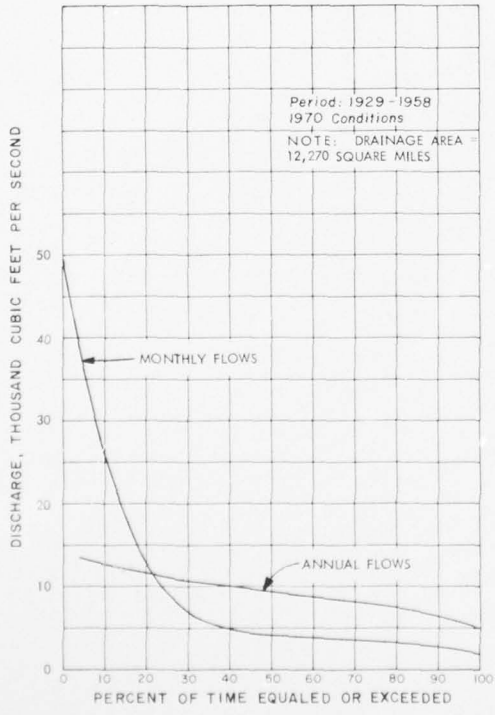


Figure 389 Duration curves, Salmon River near French Creek, Idaho

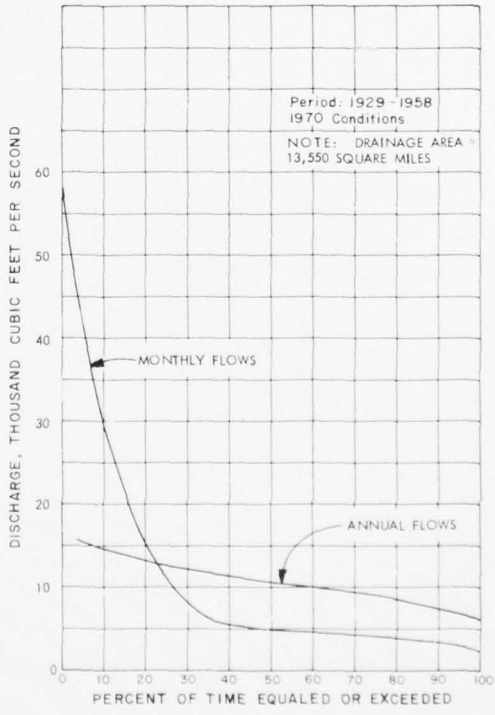


Figure 390 Duration curves, Salmon River at Whitebird, Idaho

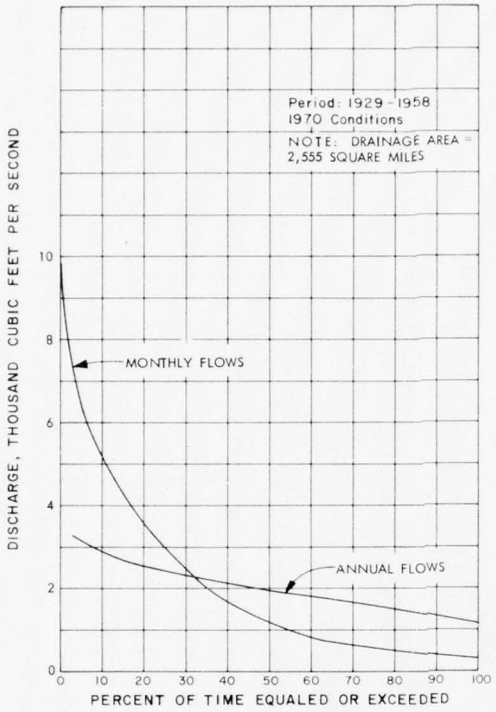


Figure 391 Duration curves, Grande Ronde River at Rondowa, Oregon

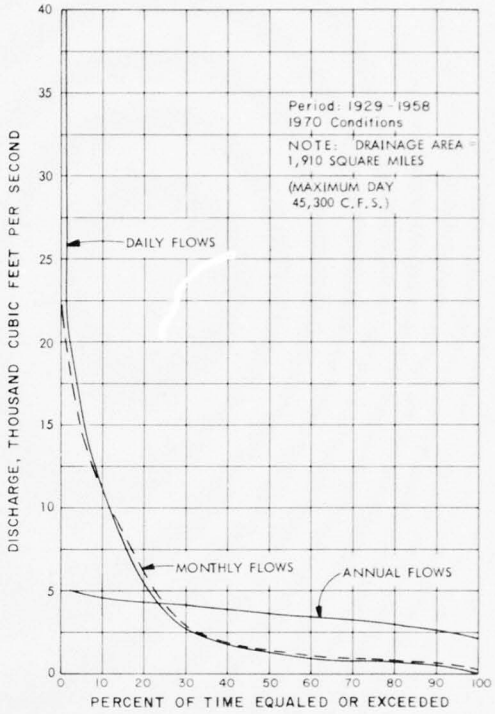


Figure 392 Duration curves, Selway River near Lowell, Idaho

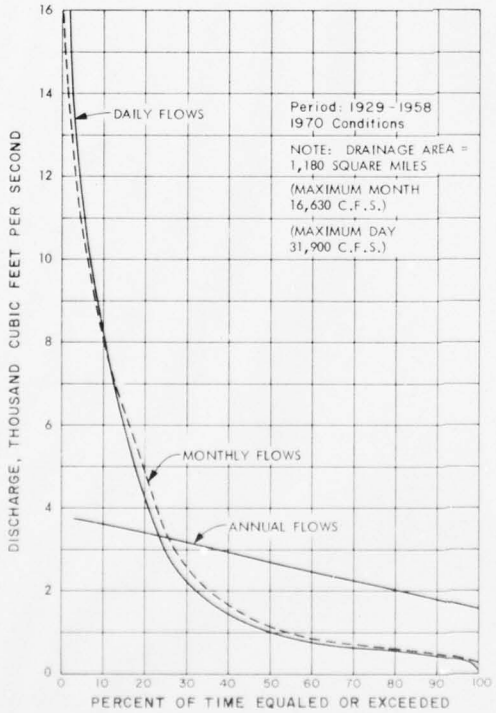


Figure 393 Duration curves, Lochsa River near Lowell, Idaho

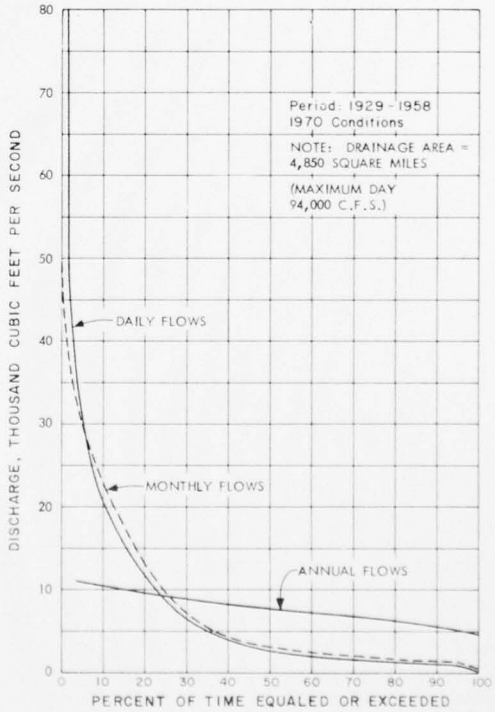


Figure 394 Duration curves, Clearwater River at Kamiah, Idaho

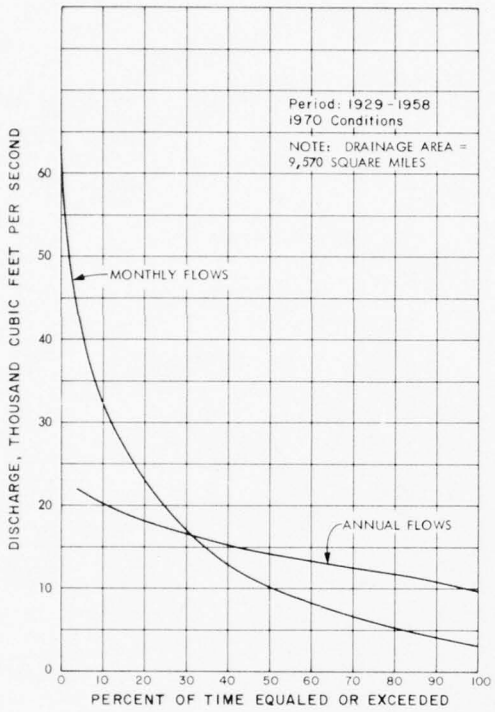


Figure 395 Duration curves, Clearwater River at Spalding, Idaho

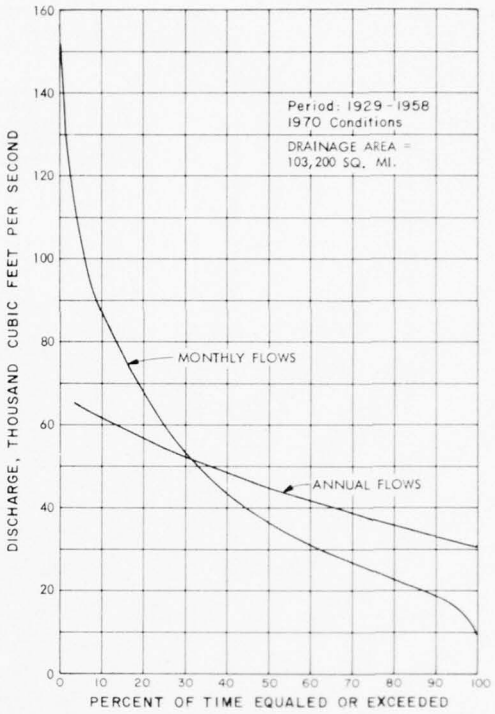


Figure 396 Duration curves, Snake River near Clarkston, Wash.

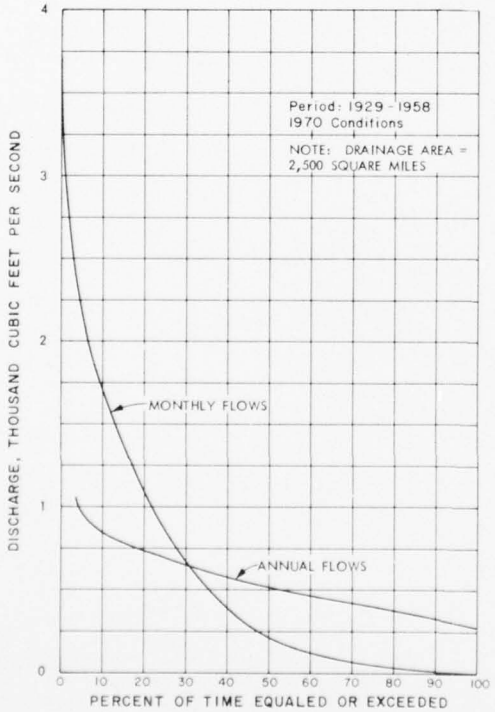


Figure 397 Duration curves, Palouse River at Hooper, Washington

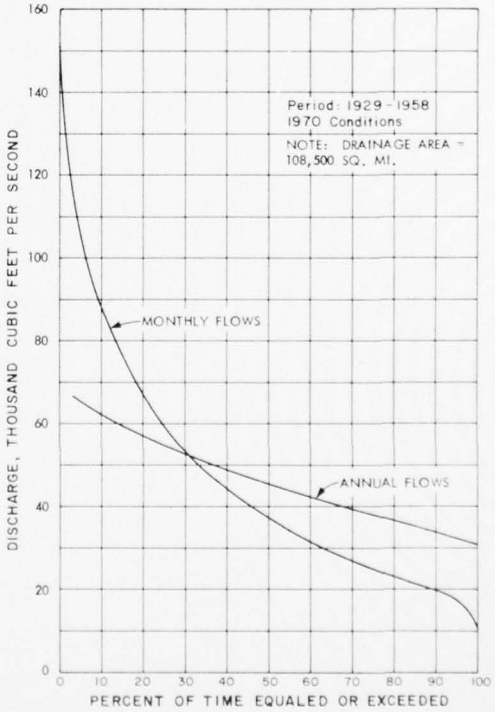


Figure 398 Duration curves, Snake River below Ice Harbor Dam, Washington

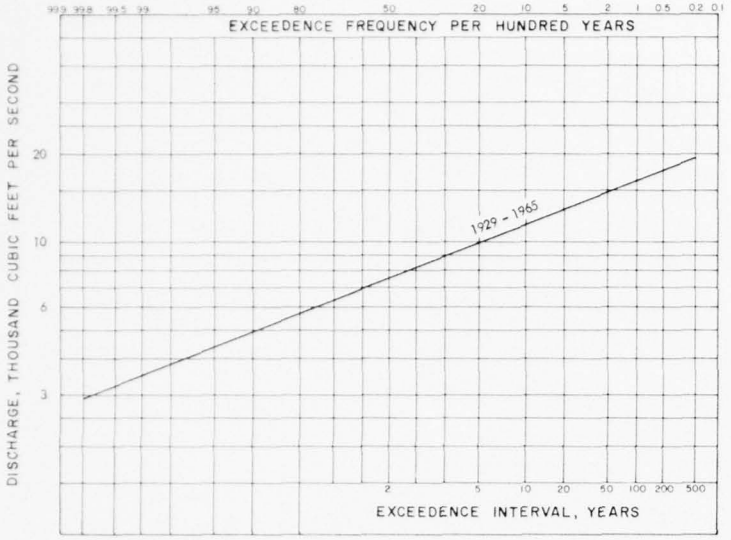


Figure 399 Frequency curve of annual peak flows, Salmon River near Challis, Idaho

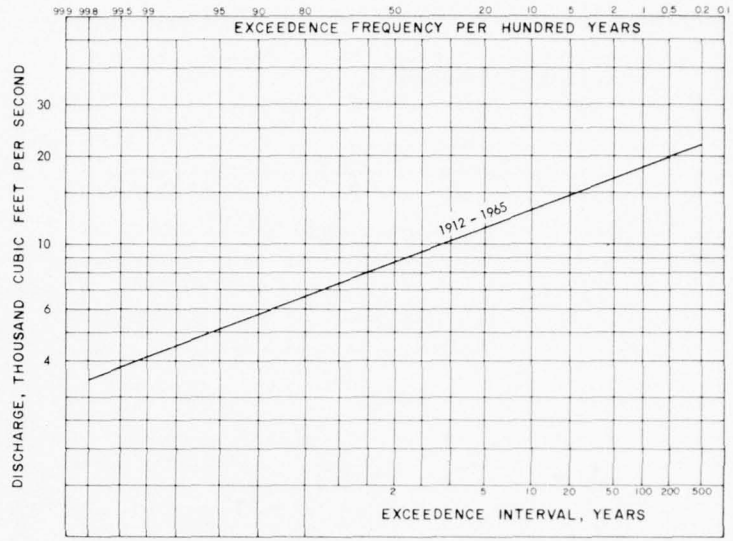


Figure 400 Frequency curve of annual peak flows, Salmon River at Salmon, Idaho

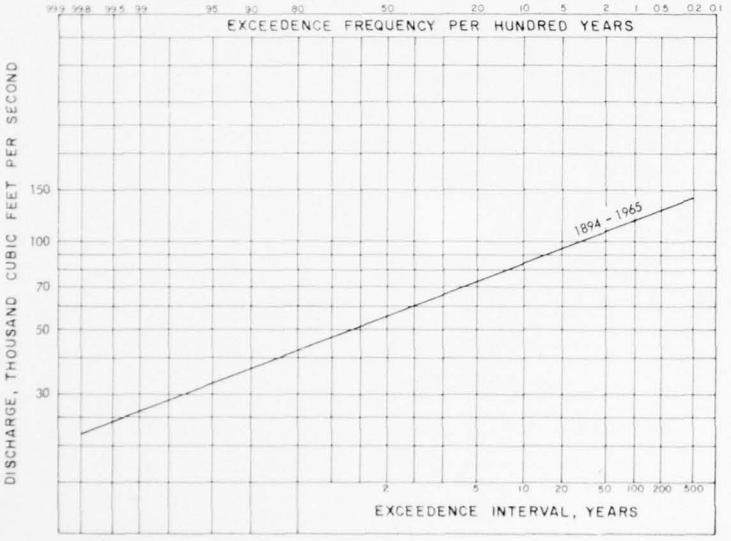


Figure 401 Frequency curve of annual peak flows, Salmon River near French Creek, Ida.

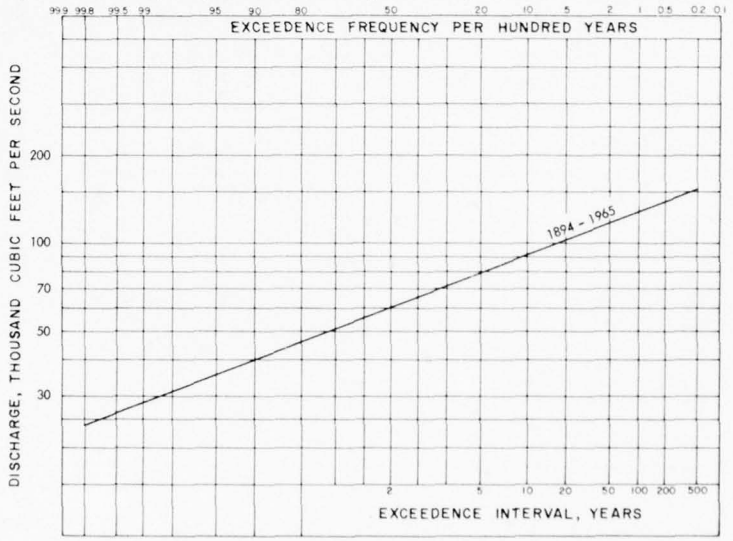


Figure 402 Frequency curve of annual peak flows, Salmon River at Whitebird, Idaho

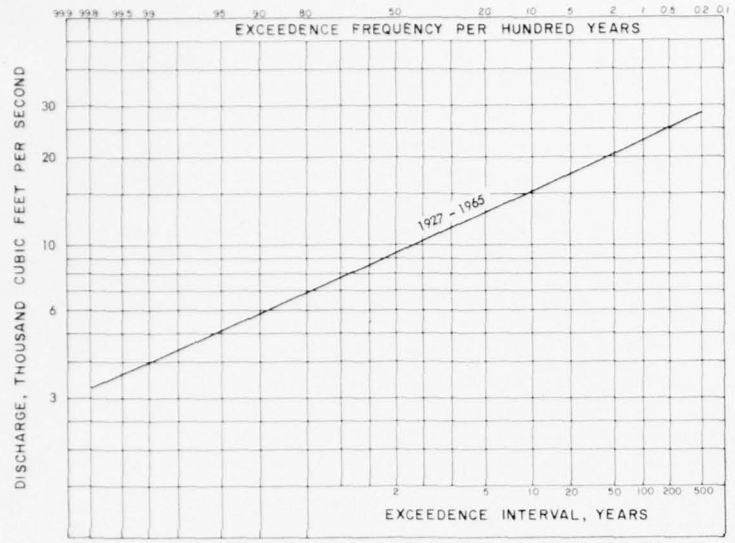


Figure 403 Frequency curve of annual peak flows, Grande Ronde River at Rondowa, Oregon

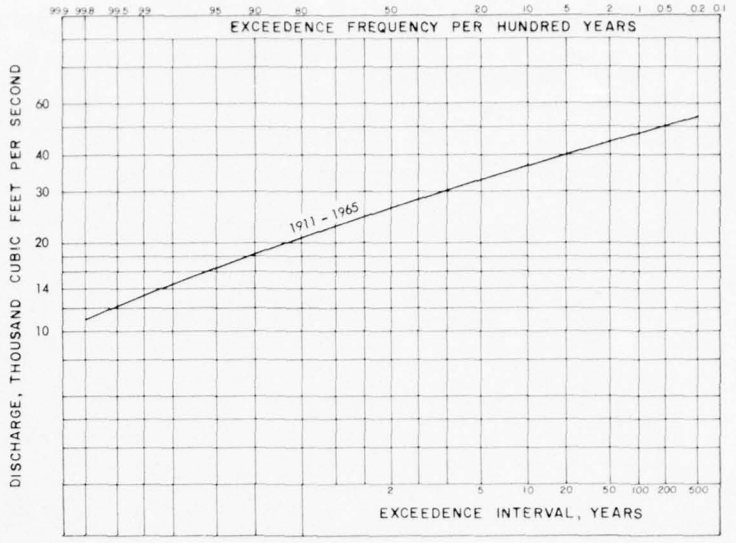


Figure 404 Frequency curve of annual peak flows, Selway River near Lowell, Idaho

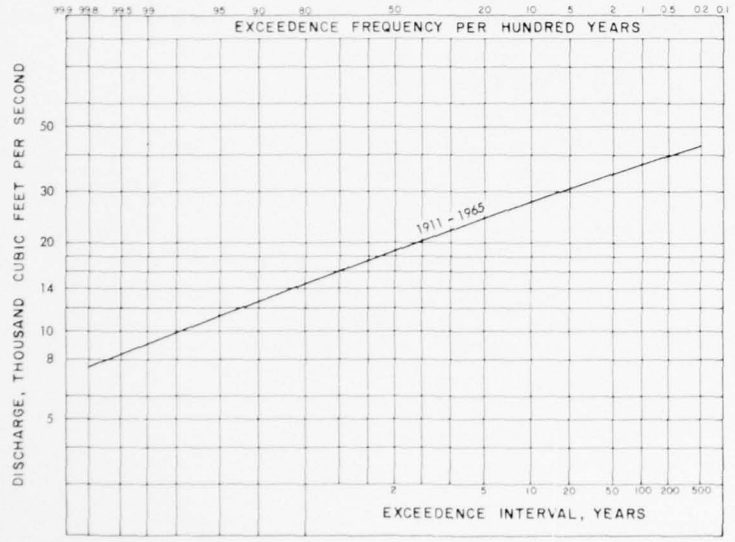


Figure 405 Frequency curve of annual peak flows, Lochsa River near Lowell, Idaho

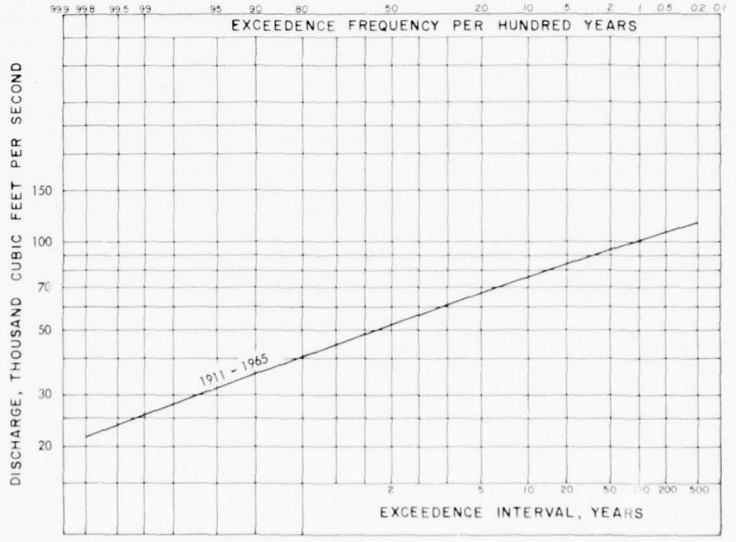


Figure 406 Frequency curve of annual peak flows, Clearwater River at Kamiah, Idaho

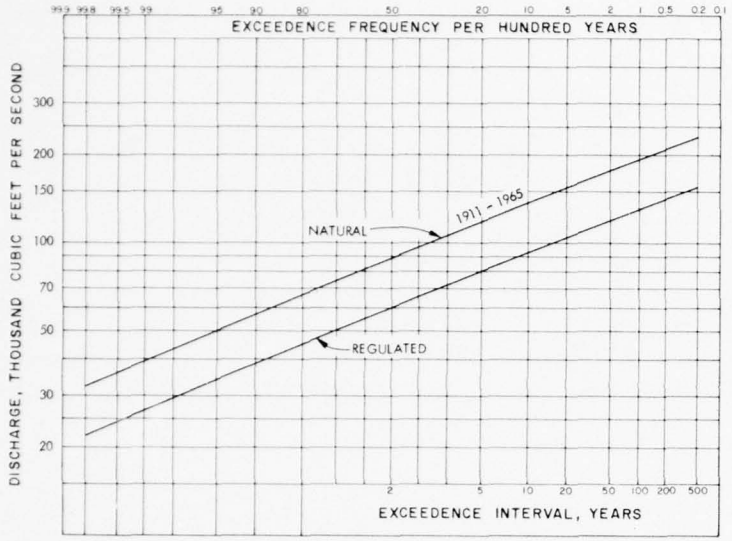


Figure 407 Frequency curve of annual peak flows, Clearwater River at Spalding, Idaho

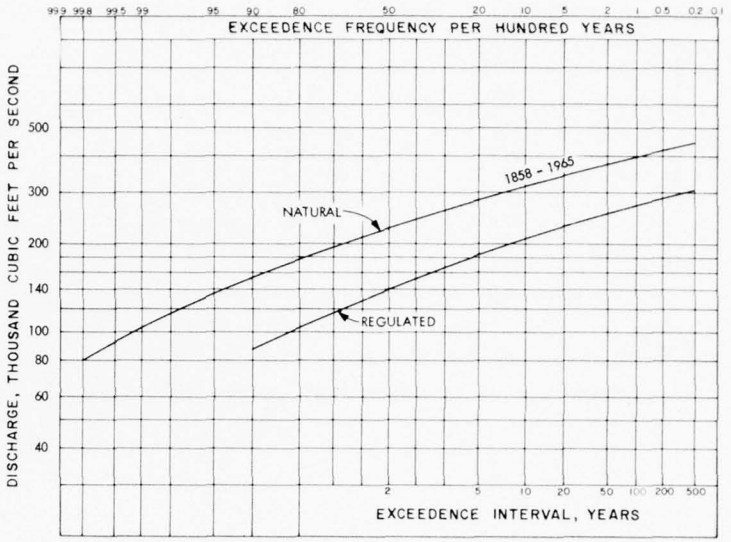


Figure 408 Frequency curve of annual peak flows, Snake River near Clarkston, Wash.

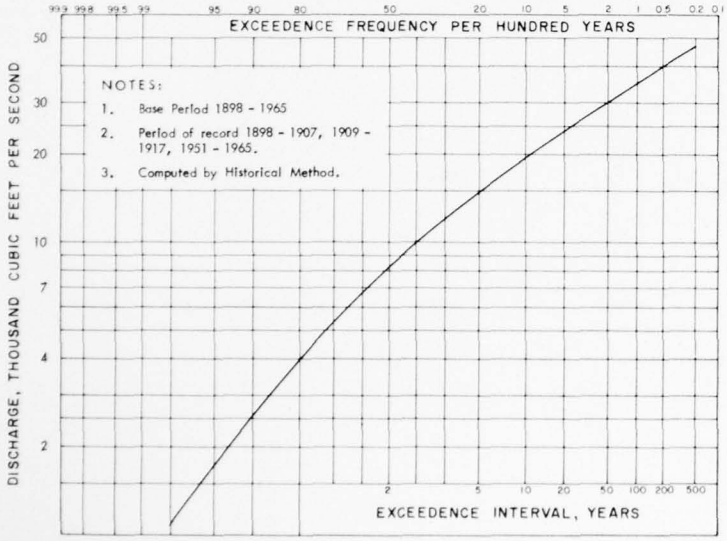


Figure 409 Frequency curve of annual peak flows, Palouse River at Hooper, Wash.

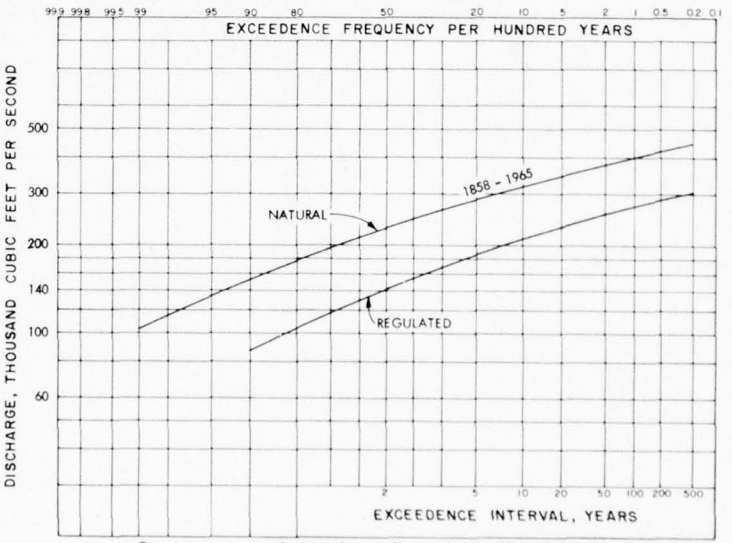


Figure 410 Frequency curve of annual peak flows, Snake River below Ice Harbor Dam, Washington

Table 221 - Dependable Yield, Salmon River near Challis, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	855	58.6
2	1930-31	1,032	70.7
3	1929-31	1,042	71.4
4	1929-32	1,129	77.4
5	1931-35	1,120	76.8
6	1930-35	1,135	77.8
7	1929-35	1,124	77.0
8	1930-37	1,149	78.8
9	1929-37	1,139	78.1
10	1931-40	1,186	81.3
30	1929-58	1,459	100.0

Table 222 - Dependable Yield, Salmon River at Salmon, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1937	1,157	61.0
2	1930-31	1,345	70.9
3	1929-31	1,357	71.5
4	1929-32	1,472	77.6
5	1929-33	1,500	79.0
6	1929-34	1,466	77.2
7	1929-35	1,458	76.8
8	1929-36	1,491	78.6
9	1929-37	1,454	76.6
10	1929-38	1,512	79.7
30	1929-58	1,898	100.0

Table 223 - Dependable Yield, Salmon River near French Creek, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	4,957	53.7
2	1930-31	6,126	66.4
3	1929-31	6,405	69.4
4	1934-37	6,802	73.7
5	1933-37	7,205	78.1
6	1930-35	7,300	79.1
7	1929-35	7,252	78.6
8	1930-37	7,205	78.1
9	1929-37	7,179	77.8
10	1930-39	7,502	81.3
30	1929-58	9,230	100.0

Table 224 - Dependable Yield, Salmon River at Whitebird, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	5,792	54.2
2	1930-31	7,170	67.1
3	1929-31	7,491	70.1
4	1934-37	7,978	74.6
5	1933-37	8,435	78.9
6	1930-35	8,536	79.8
7	1929-35	8,479	79.3
8	1930-37	8,431	78.9
9	1929-37	8,399	78.6
10	1929-38	8,786	82.2
30	1929-58	10,690	100.0

Table 225 - Dependable Yield, Grande Ronde River at Rondowa, Oregon

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	1,175	57.5
2	1930-31	1,250	61.2
3	1929-31	1,339	65.5
4	1934-37	1,513	74.0
5	1934-38	1,594	78.0
6	1934-39	1,595	78.0
7	1934-40	1,583	77.4
8	1934-41	1,591	77.8
9	1933-41	1,656	81.0
10	1933-42	1,719	84.1
30	1929-58	2,044	100.0

Table 226 - Dependable Yield, Selway River near Lowell, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	2,233	62.0
2	1940-41	2,514	69.8
3	1929-31	2,664	73.9
4	1939-42	2,896	80.4
5	1937-41	2,779	77.1
6	1937-42	2,883	80.0
7	1936-42	2,985	82.8
8	1935-42	2,987	82.9
9	1934-42	3,110	86.3
10	1933-42	3,196	88.7
30	1929-58	3,604	100.0

Table 227 - Dependable Yield, Lochsa River near Lowell, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	1,581	58.3
2	1940-41	1,865	68.8
3	1929-31	1,926	71.0
4	1939-42	2,078	76.6
5	1938-42	2,184	80.5
6	1937-42	2,107	77.7
7	1936-42	2,168	79.9
8	1935-42	2,180	80.4
9	1934-42	2,338	86.2
10	1935-44	2,273	83.8
30	1929-58	2,712	100.0

Table 228 - Dependable Yield, Clearwater River at Kamiah, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	4,755	62.0
2	1940-41	5,298	69.0
3	1939-41	5,618	73.2
4	1938-41	6,012	78.3
5	1937-41	5,789	75.4
6	1937-42	6,050	78.8
7	1935-41	6,066	79.0
8	1935-42	6,227	81.1
9	1934-42	6,501	84.7
10	1935-44	6,491	84.6
30	1929-58	7,674	100.0

Table 229 - Dependable Yield, Clearwater River at Spalding, Idaho

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1941	9,826	67.4
2	1929-30	10,644	73.0
3	1929-31	10,593	72.7
4	1939-42	11,178	76.7
5	1938-42	11,543	79.2
6	1937-42	11,283	77.4
7	1936-42	11,693	80.2
8	1935-42	11,737	80.5
9	1937-45	12,107	83.1
10	1937-46	12,282	84.3
30	1929-58	14,573	100.0

Table 230 - Dependable Yield, Snake River near Clarkston, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	31,206	68.1
2	1930-31	32,273	70.4
3	1929-31	33,151	72.3
4	1929-32	34,967	76.3
5	1929-33	36,704	80.0
6	1929-34	37,321	81.4
7	1929-35	36,778	80.2
8	1929-36	37,292	81.3
9	1929-37	36,671	80.0
10	1929-38	37,644	82.1
30	1929-58	45,850	100.0

Table 231 - Dependable Yield, Palouse River at Hooper, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1937	256	47.1
2	1929-30	332	61.1
3	1929-31	339	62.4
4	1929-32	362	66.7
5	1929-33	368	67.8
6	1936-41	392	72.2
7	1935-41	406	74.8
8	1935-42	418	77.0
9	1933-41	428	78.8
10	1932-41	430	79.2
30	1929-58	543	100.0

Table 232 - Dependable Yield, Snake River Below Ice Harbor Dam, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1929-58 Mean
1	1931	31,029	67.5
2	1930-31	31,752	69.0
3	1929-31	32,647	71.0
4	1929-32	34,753	75.6
5	1929-33	36,675	79.8
6	1929-34	37,418	81.4
7	1929-35	36,900	80.2
8	1929-36	37,440	81.4
9	1929-37	36,854	80.1
10	1929-38	37,901	82.4
30	1929-58	45,984	100.0

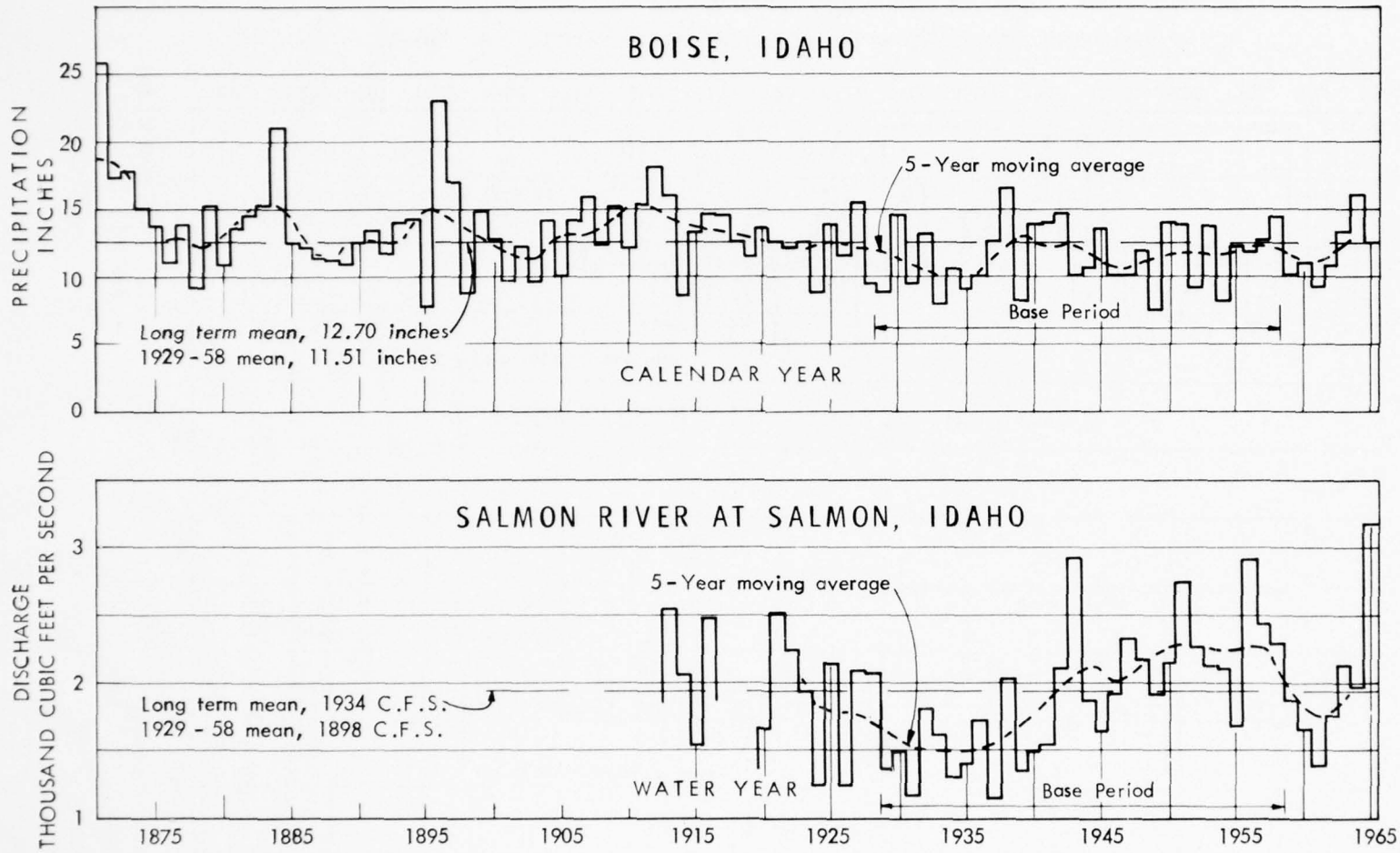


FIGURE 411 LONG-TERM VARIATION IN PRECIPITATION AND STREAMFLOW

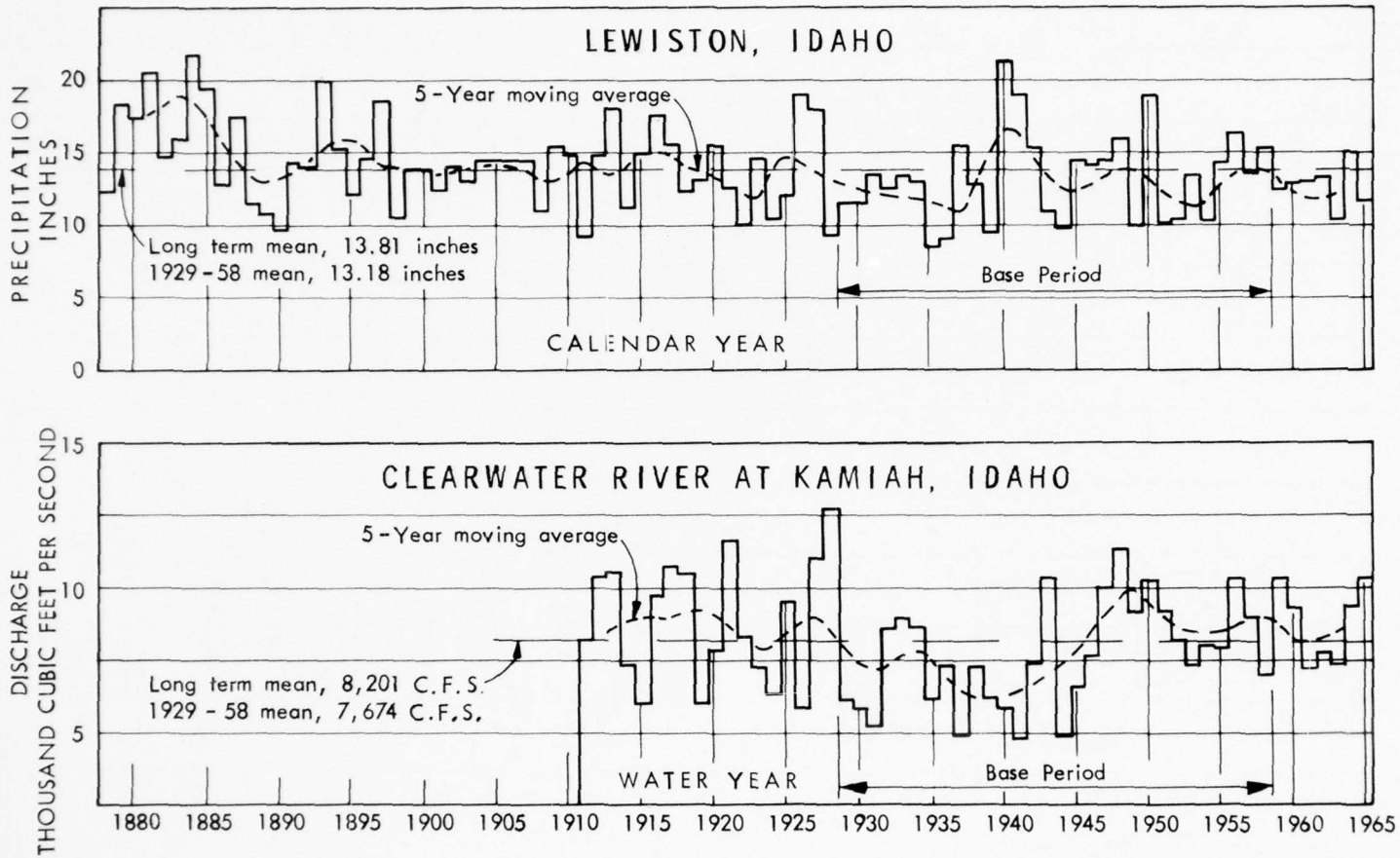


FIGURE 412 LONG - TERM VARIATION IN PRECIPITATION AND STREAMFLOW

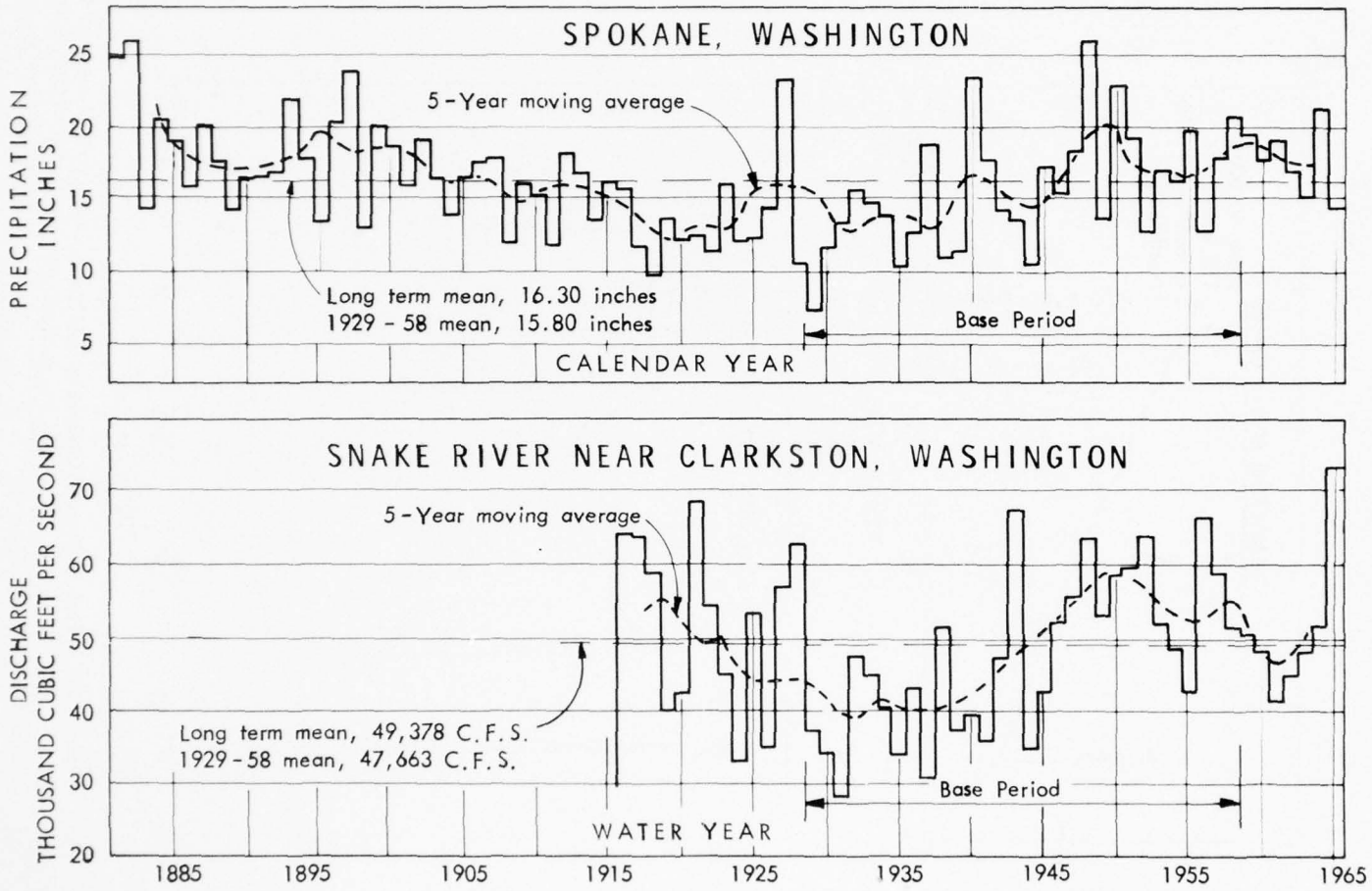
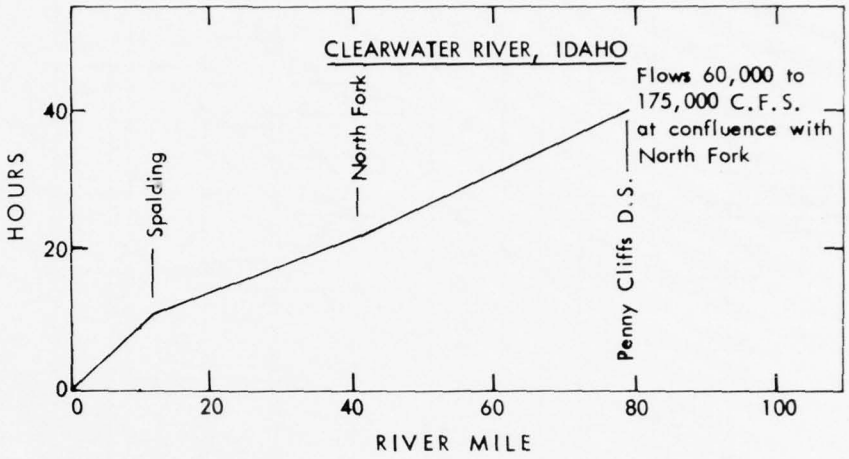


FIGURE 413 LONG - TERM VARIATION IN PRECIPITATION AND STREAMFLOW



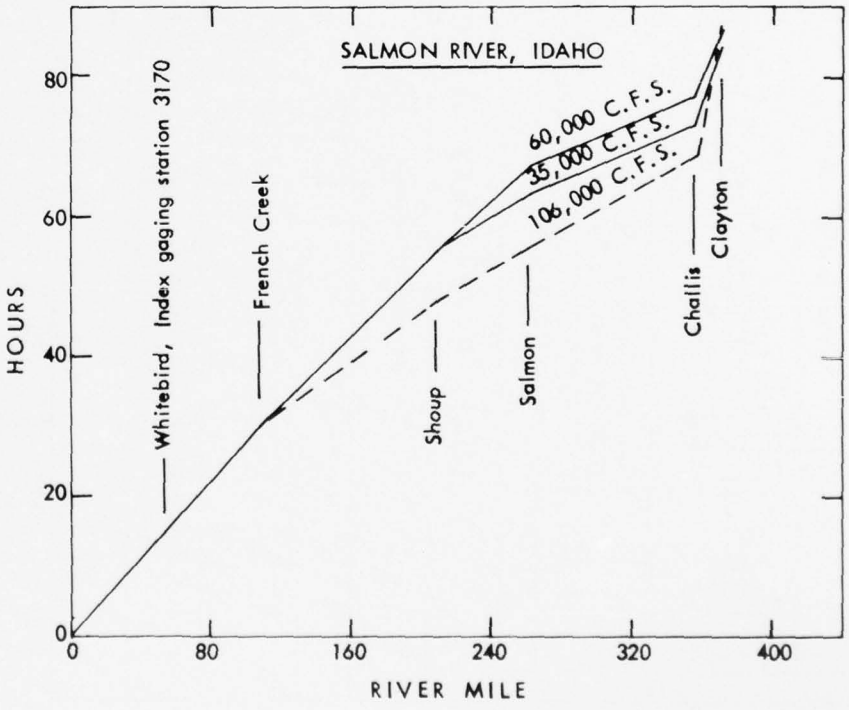
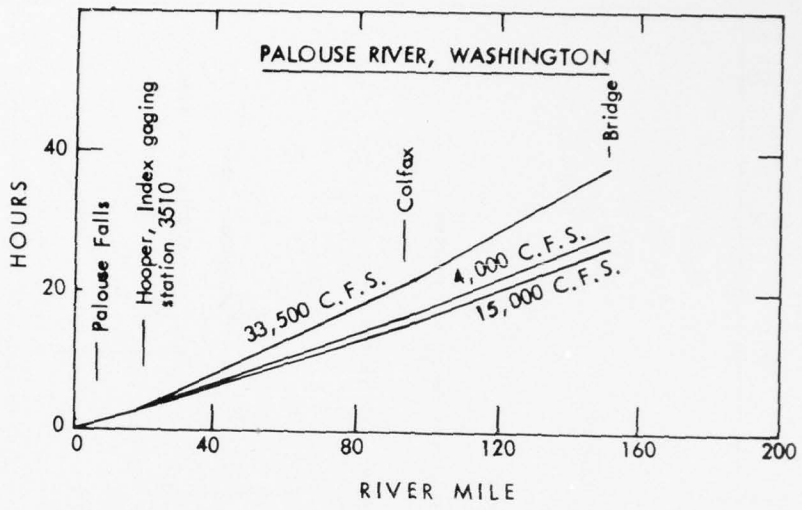


Figure 414 Time of travel, Clearwater and Salmon Rivers



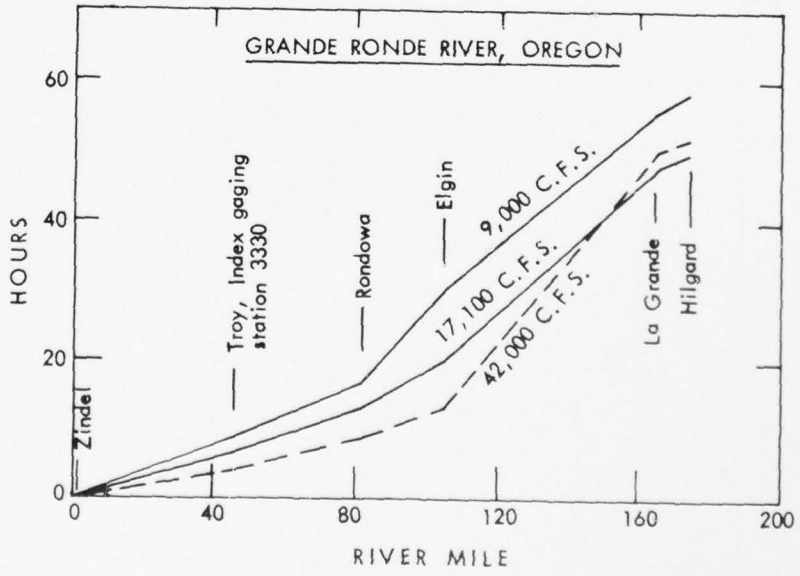


Figure 415 Time of travel, Palouse and Grande Ronde Rivers

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COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY OF --ETC(U)
APR 70 G L BODHAINE, H D HAFTERSON

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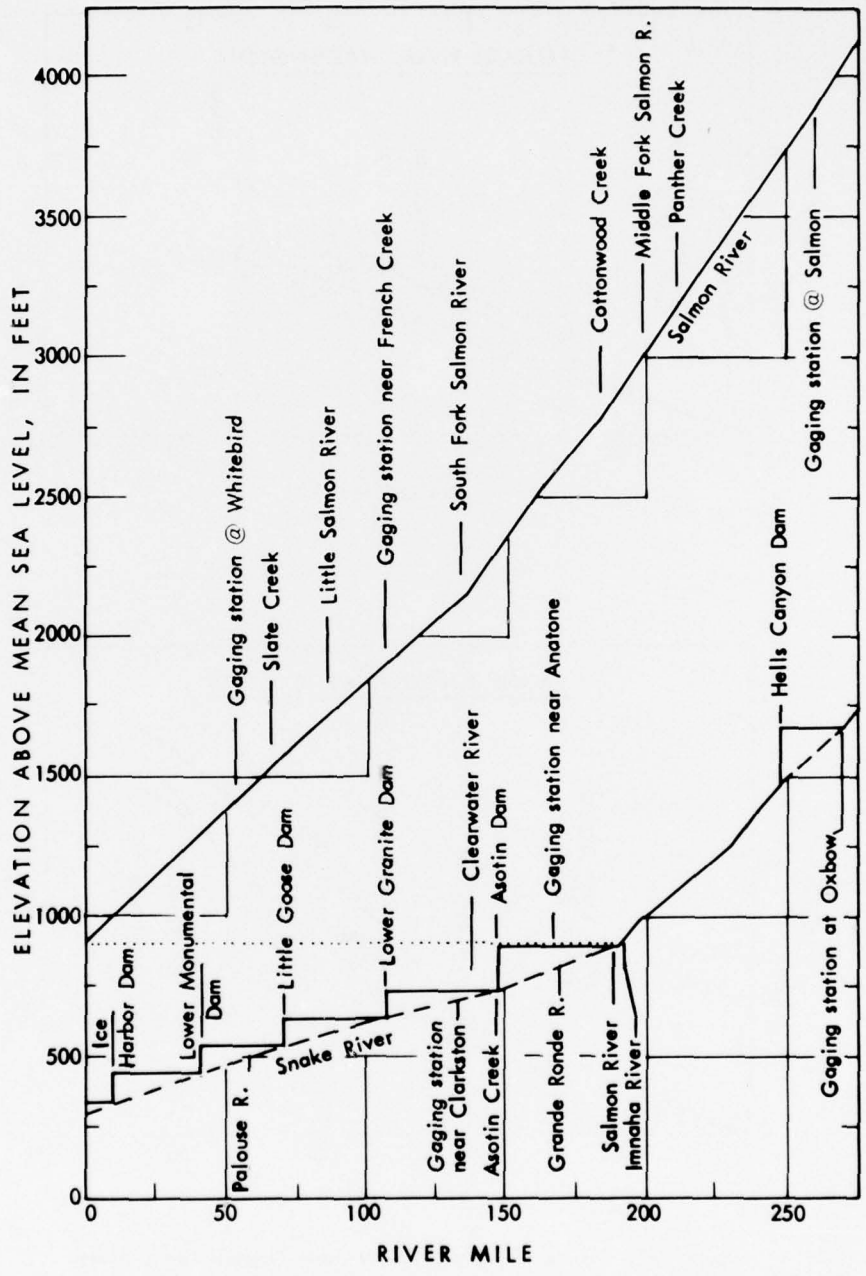


Figure 416 Stream profile, Lower Snake and Salmon Rivers

Quality

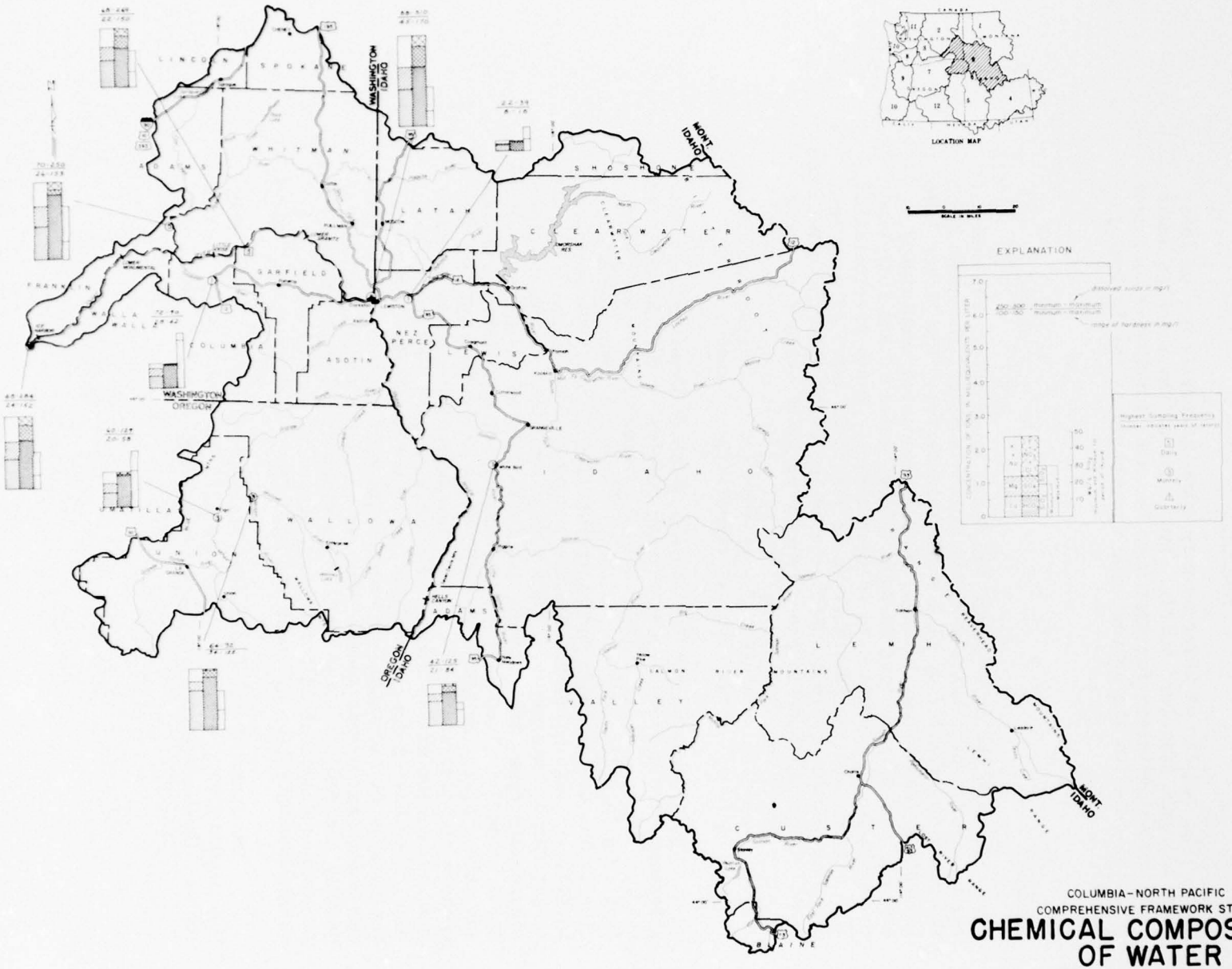
The quality of water is very good, generally having less than 100 mg/l dissolved solids. Even that of the mainstem Snake River is satisfactory for most uses because of tributary dilution. Detailed data for the subregion are presented on the following pages.

Chemical

Between the point where the Snake River enters the subregion and its confluence with the Columbia River, the quality of the river is affected by five major tributaries. The Salmon River in central Idaho flows through sparsely populated mountainous areas. Most of this area is underlain by volcanic and intrusive rocks which are resistant to solvent action. Heavy precipitation, high runoff, and the resistant rocks result in water of very low dissolved-solids content. With the exception of the Pahsimeroi and Lemhi Rivers which drain areas containing limestone and are more highly mineralized, 200-300 mg/l dissolved solids content, all streams sampled have contained less than 100 mg/l dissolved solids (64). Figure 417 shows chemical composition of water.

The mineral quality of the Grande Ronde River and its major tributary, the Wallowa River, is very similar to that of the Salmon River. The headwaters contain dilute calcium bicarbonate waters of less than 75 mg/l dissolved solids. Use of the water for irrigation in the Grande Ronde and Wallowa Valleys causes some downstream increase in mineralization but the chemical composition of the water is not changed appreciably. The waters are still of the calcium bicarbonate type with slightly larger amounts of sodium and sulfate. The average dissolved-solids concentration of both the Grande Ronde and Salmon Rivers as they enter the Snake River is about 100 mg/l. Because the combined flow of these two tributaries makes up more than 40 percent of the flow of the Snake River below their confluence, they have a considerable diluting effect on the Snake River. The average dissolved-solids concentration of the Snake River above the Salmon and Grande Ronde Rivers is in excess of 300 mg/l. Monthly samples collected from Snake River near Clarkston, below the Grande Ronde and Salmon Rivers, showed an average dissolved-solids concentration of about 200 mg/l for the river at that point.

The water of the Clearwater River is even more dilute than the Salmon River, averaging about 33 mg/l dissolved solids at the mouth. The Clearwater River has the largest runoff of the Snake



COLUMBIA–NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

CHEMICAL COMPOSITION OF WATER

LOWER SNAKE SUBREGION 6

1968

FIGURE 417

River tributaries and further dilutes the mineralization of the main stem. At Central Ferry, near Pomeroy, Washington, the average dissolved-solids concentration of the Snake River is less than 150 mg/l.

The two principal tributaries between the Clearwater River and the mouth of Snake River are the Palouse and Tucannon Rivers. These two tributaries flow through a part of the relatively flat Columbia Plateau. In many places the soil, which is a loess and highly susceptible to erosion, increases the solution of minerals by the water, thus producing greater mineralization than would be expected in an area underlain by basalt (64-32). The Palouse River drains a much larger area of these soils than the Tucannon River and its mineralization is much greater, averaging about 170 mg/l dissolved solids at the mouth.

The Palouse and Tucannon Rivers have little effect on the Snake River because their flows are relatively small compared to that of the mainstem. The water of the Snake River at its confluence with the Columbia River is very similar in chemical character to what it is upstream at Central Ferry.

In some irrigated areas in the Wallowa River Valley there are drainage problems; in the Grande Ronde River Basin both drainage and alkali accumulation problems occur. Large increases in irrigation use should be prefaced by thorough studies to define the extent and seriousness of these problems.

The mineral quality of all streams in the basin is suitable for the foreseeable uses. Although some increases of mineralization occur in irrigated areas, the water is still suitable for irrigation use.

Biological-Biochemical

Information collected over a considerable period of time on dissolved oxygen and coliform organisms concentrations in streams is presented in the accompanying table 233.

Dissolved oxygen levels are generally high and relatively few related problems exist. Flows in portions of the South Fork of the Palouse River are seasonally depleted to the point that waste discharges constitute the major flow of the river.

As in other subregions of the Snake River drainage, bacterial densities vary considerably, with unsuitable conditions occurring below a number of communities. Some bacterial contamination of sewage origin enters the Clearwater and Snake Rivers in the Lewiston-Clarkston area. Bacterial levels do not indicate a serious problem;

however; during the summer they are higher than the recommended level of 1,000 organisms/100 ml for water contact recreation.

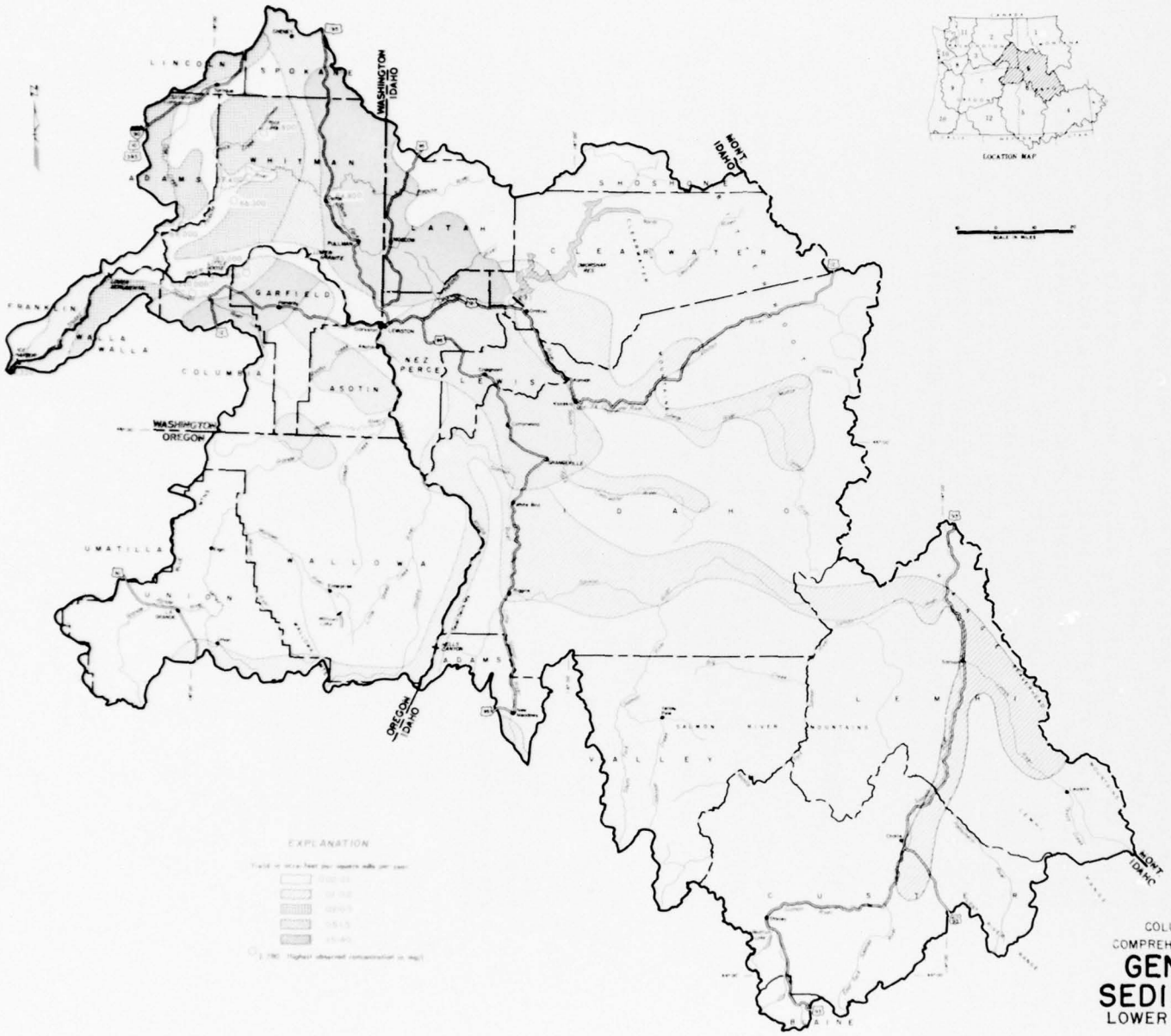
Over the years, the water pollution surveillance station at Wawawai has recorded high levels of plankton productivity. While the organisms--mostly diatoms--are beneficent, the conditions that produce them also are responsible for nuisance growths which are present in many areas.

Table 233. Dissolved Oxygen & Coliform Organisms Densities
Lower Snake Subregion

Location	Dissolved Oxygen mg/l			Coliform Organisms /100 ml		
	Mean	Min	Max	Mean	Min	Max
Wallowa R. at Minam	10.5	7.2	12.8	1,383	60	6,200
Grande Ronde R. nr. Elgin	10.0	6.0	12.7	829	60	7,000
Clearwater R. at Lewiston	10.6	5.0	14.8	-	-	-
Snake R. nr. Wawawai	10.8	7.0	16.0	-	-	-
Snake R. at Hwy 410	11.4	7.6	21.0	449	0	4,600
Tucannon R. nr. Delaney	10.8	8.1	12.4	51,331	910	460,000
Palouse R. nr. Hooper	11.2	5.3	14.2	9,089	91	110,000
Snake R. nr. Ice Harbor Dam	11.1	7.9	14.3	-	-	-
Snake R. nr. Pasco	11.1	7.1	17.0	682	0	9,300

Sediment

Extensive data have been collected on sediment transport and deposition, especially in Palouse River Basin. Suspended-sediment data were obtained mostly during the period 1934-40, but also in 1905, 1910-12, 1951-52, and since 1962. Figure 418 shows maximum concentrations of sediment observed in some streams since 1962, the highest concentration being 383,000 mg/l in Deadman Creek. The highest observed concentrations occurred during the flood of December 1964. The flood was caused by heavy rainfall on snow lying on frozen ground. Most of the precipitation became surface runoff which caused severe channel, sheet, and rill erosion in the north part of Garfield County, Washington. Runoff at lower elevations, while producing heavy sediment concentrations, did not cause a high sediment yield. (64)



COLUMBIA-NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERALIZED SEDIMENT YIELD

LOWER SNAKE SUBREGION 6

1968

FIGURE 418

During the period 1941-51, sediment deposition studies were made in Asotin Creek and Clearwater River Basins. These studies also showed quite high rates of sediment transport. Figure 418 shows sediment yields (30) ranging from 0.02 acre-feet per square mile per 3 year in the mountainous areas to 4.0 acre-feet per square mile per year in the highly erosive dryfarm areas of southeastern Washington. In the area known as the Palouse Wheat Belt, about one-half the cultivated land had been seriously damaged through the loss of topsoil. The most severe erosion occurs as a result of (1) rains of long duration and relatively low intensities falling on wet or saturated soil, (2) melting snow, with or without rain, on frozen soil, (3) runoff across lower slopes and bottomland resulting from melting snowdrifts on the steep north slopes, and (4) high-intensity summer rains confined to small areas. (30) Water erosion dominates in the more humid localities but there is also some wind erosion in the drier areas. Sedimentation also occurs in a few areas as a result of past overgrazing and current mining and road building activities.

Water Temperature

Water temperature data have been collected in sufficient quantity in the lower 270 miles of Snake River to develop temperature profiles for July, as shown on figure 419. The temperatures of entering tributaries are also given, and their cooling effect on the mainstem is clearly evident by the sharp drops in the profile.

For the 22-year period (1944-1965), the temperature in July has ranged from 62° to 77°F. The maximum temperature ranged from 74°F. at mile 270 to 77°F. at the mouth.

Figure 420 compares Snake River monthly temperatures at four stations for periods varying from 8 to 13 years. The annual range is from about 34°F. in January to about 77°F. in July and August.

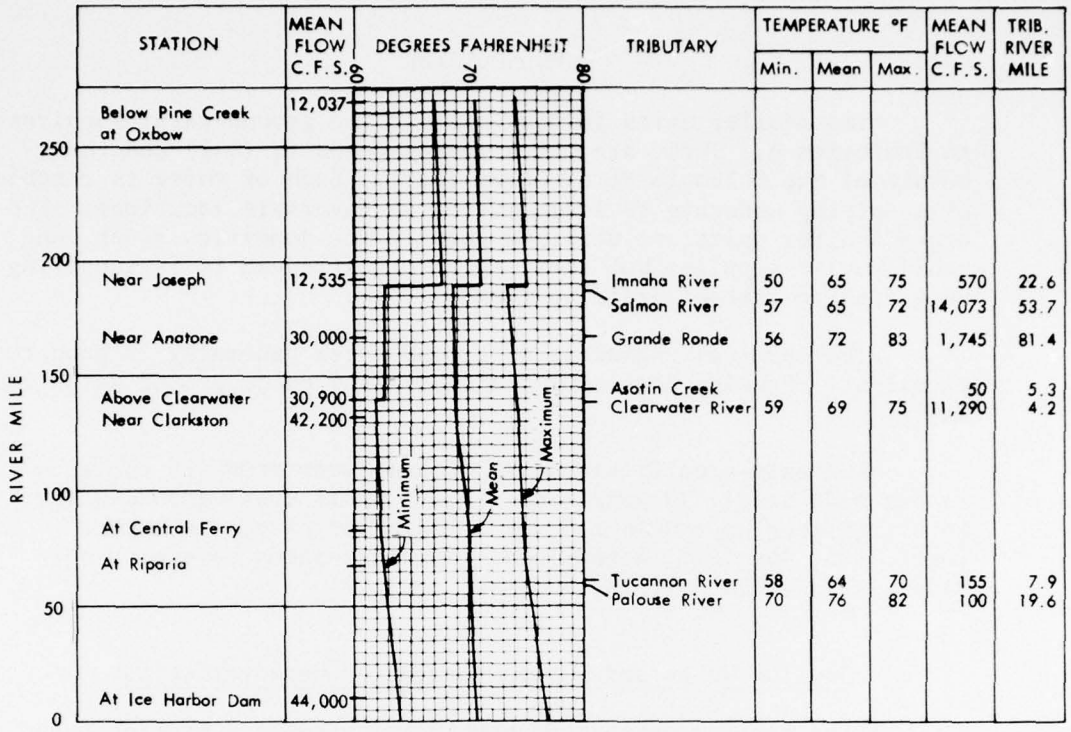


FIGURE 419 WATER TEMPERATURE PROFILES FOR JULY, LOWER SNAKE RIVER, 1944 - 1965

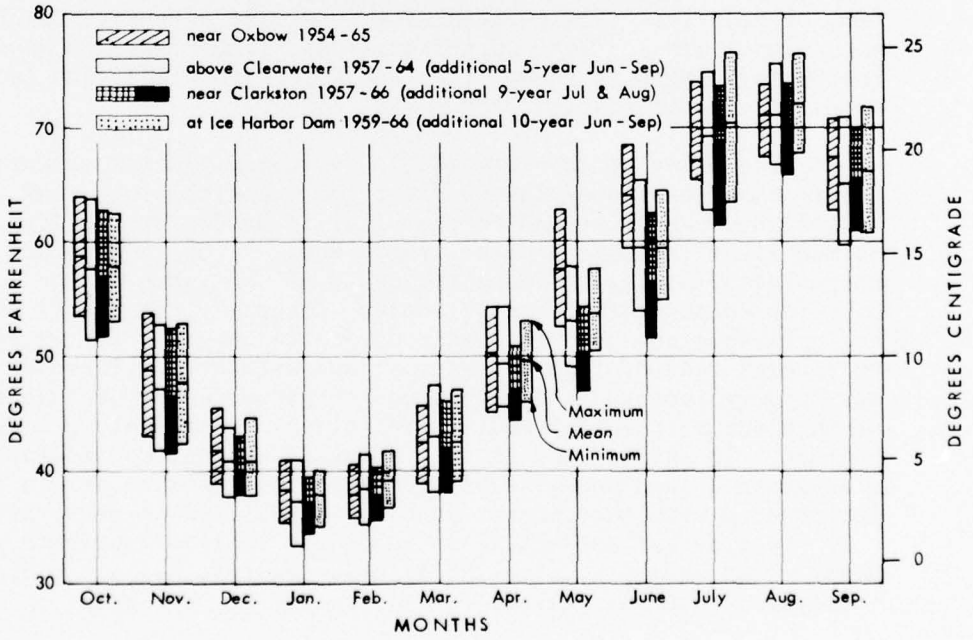


FIGURE 420 MONTHLY WATER TEMPERATURES, LOWER SNAKE RIVER

GROUND WATER

Two aquifer units furnish most of the ground-water supplies in Subregion 6. These are the alluvial deposits (Qal) and the basalt of the Columbia River Group (Tcr). Each of these is capable of supplying moderate to large yields at favorable locations. The other aquifer units are utilized locally for domestic, stock, and small public supplies but their chief significance is in supplying base flow to streams draining them.

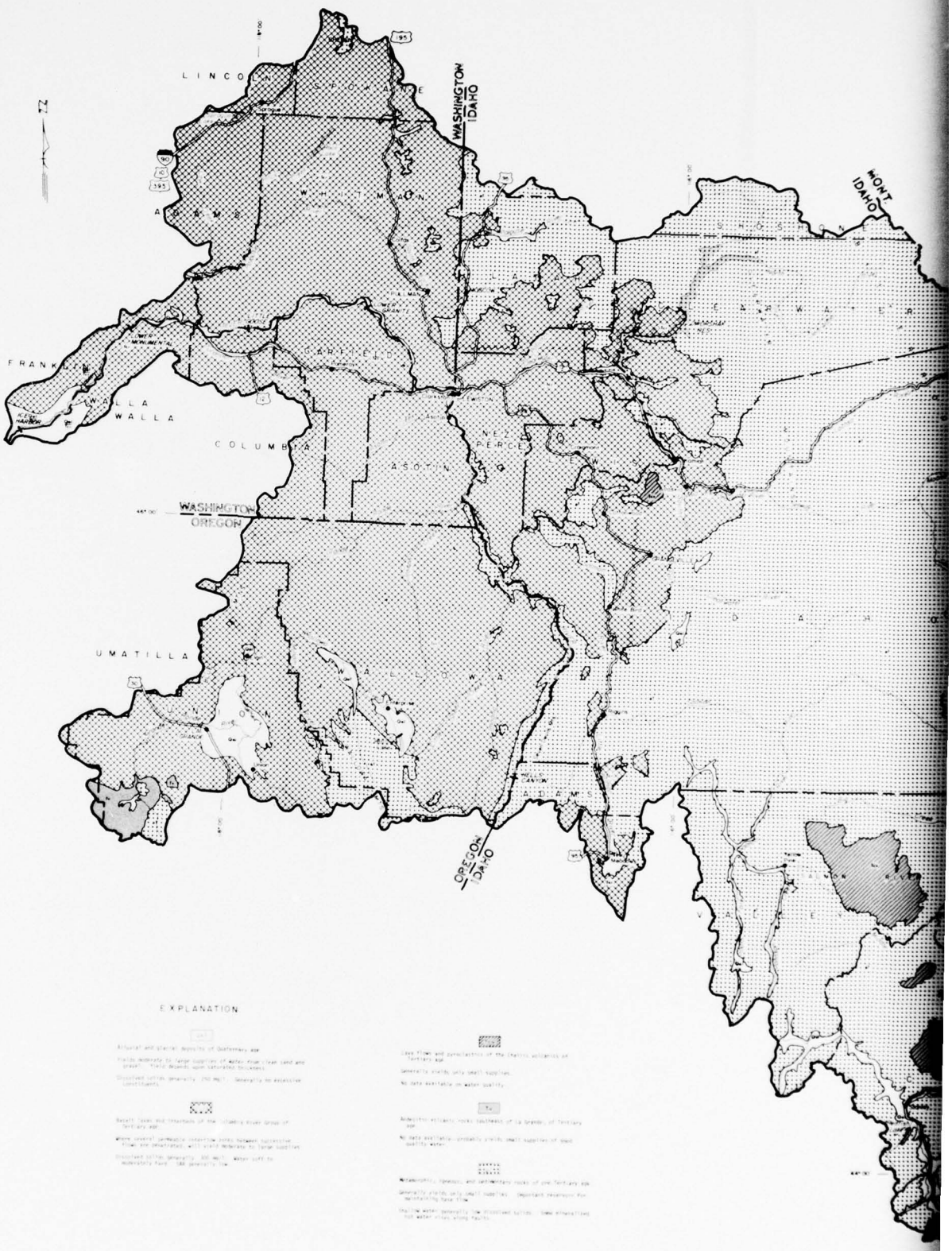
The chemical character of ground water generally is good to excellent. Present development and utilization of ground water is small.

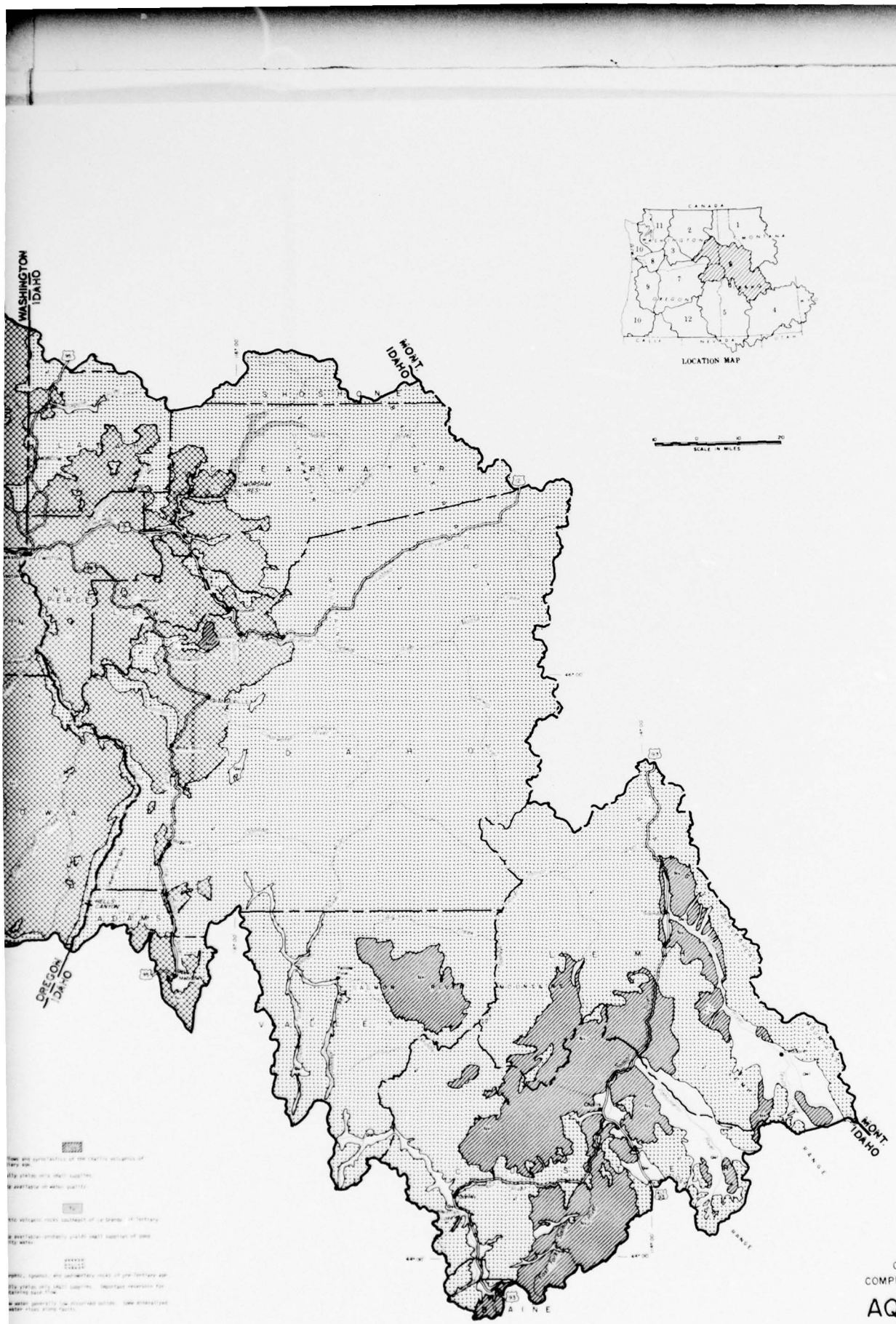
The only areally extensive ground-water study in the area is one made nearly 70 years ago. (135) Small areal ground-water investigations have been made at a few other places in recent years. (35, 46, 151) A few local reconnaissances have also been made. (22, 24, 60, 61, 78, 89)

Aquifer Units and Their Hydrologic Characteristics

Five aquifer units have been delineated in Subregion 6 and are shown on the map, figure 421. Two are good to excellent at places and are utilized for public, industrial, and irrigation supplies; one underlies a very small area and is not utilized; and two, of relatively low permeability, underlie extensive uninhabited mountainous areas. The aquifer-unit map, figure 421, is based on the Geologic Maps of Idaho (133) and Washington (54), and two maps of parts of northeastern Oregon (46, 179).

The alluvial deposits (Qal), including glacial outwash, occur as narrow flood-plain and terrace deposits along many streams and as more extensive and thicker fill in headwaters valleys of the Salmon River in Idaho and the Grande Ronde River in Oregon. Many narrow alluvial-terrace deposits could not be shown on the aquifer-unit map because of its small scale. Generally, they are coarse and permeable and will furnish moderate to large yields where ten to several tens of feet of material are saturated. These deposits may be very important local sources of ground water because many of them occur in valleys cut in relatively impermeable pre-Tertiary bedrock. In some of the broader alluvial basins, considerable fine-grained sand and silt of alluvial or lacustrine origin is interbedded with the coarser sand and gravel; wells penetrating only the fine-grained materials have only small or moderate yields. However, at many places in the alluvial basins, wells yielding 500 to several thousand gallons per minute can be developed.


LINCOLN
SPOKANE
WASHINGTON
IDAHO
ADAMS
WHITMAN
BENEWAH
SHOSHONE
CLEARWATER
FRANKLIN
GARFIELD
WALLA WALLA
COLUMBIA
ASOTIN
NEZ PERCE
LATAH
WASHINGTON
OREGON
UMATILLA
WALLOWA
OREGON
IDAHO
EXPLANATION



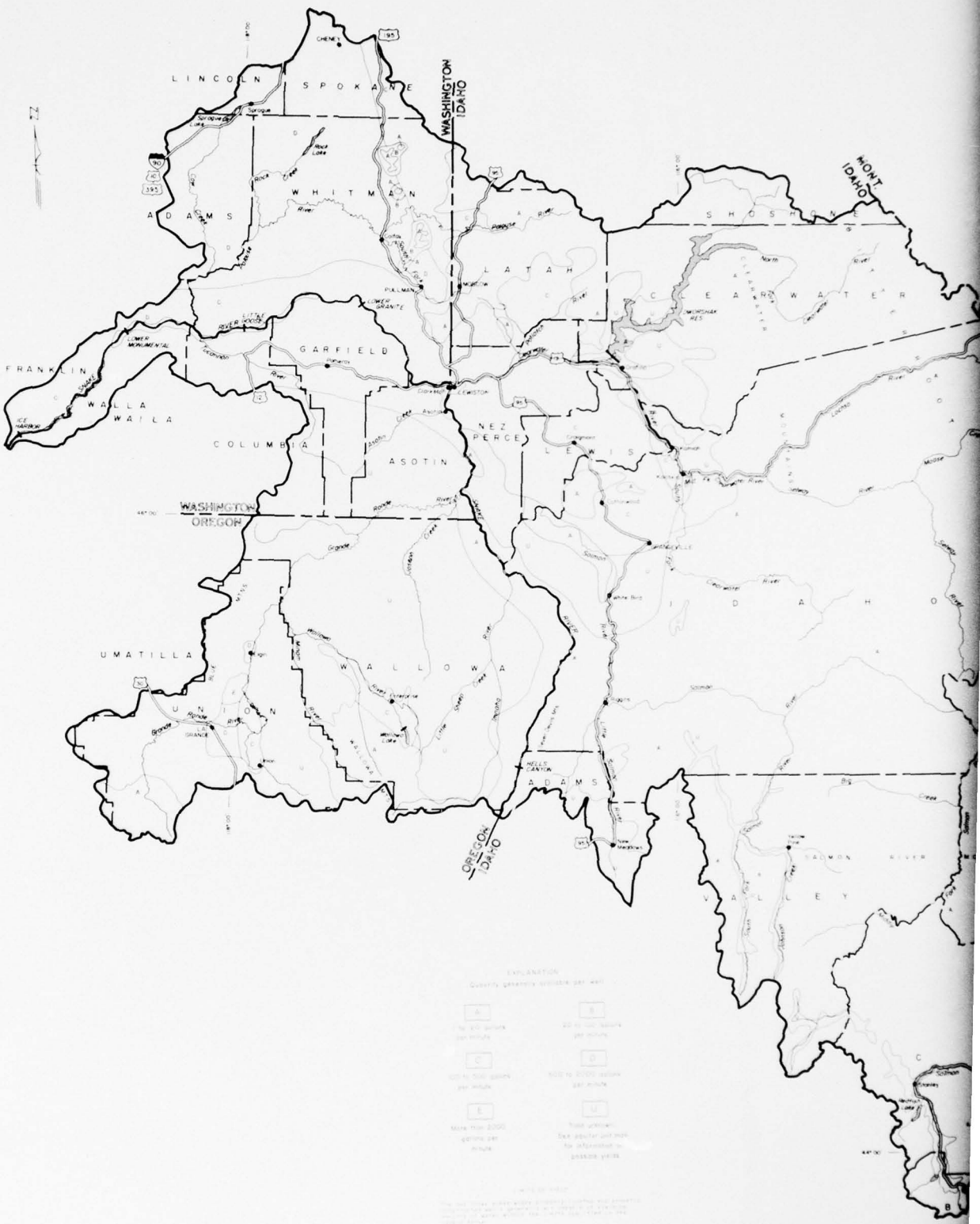
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COMPREHENSIVE FRAMEWORK STUDY

AQUIFER UNITS

LOWER SNAKE SUBREGION 6

1968

FIGURE 421


LINCOLN
SPOKANE
WASHINGTON
IDAHO
MONT.
IDAHO
ADAMS
WHITMAN
SHOSHONE
LATAH
CLEARWATER
FRANKLIN
GARFIELD
WALLA WALLA
COLUMBIA
ASOTIN
NEZ PERCE
LEWIS
WASHINGTON
OREGON
UMATILLA
WALLOWA
UNION
ADAMS
OREGON
IDAHO
IDAHO
VALLEY



COLUMBIA–NORTH PACIFIC
COMPREHENSIVE FRAMEWORK STUDY

GENERAL AVAILABILITY OF GROUND WATER

LOWER SNAKE SUBREGION 6

1968

FIGURE 422

The basalts of the Columbia River Group (Tcr) are medium to dark gray or black basalts and basaltic andesites in flows generally 25 to 100 feet thick. The basal part of each flow is very fine grained and dense; the center is dense and massive, with columnar jointing; the upper part frequently is scoriaceous or vesicular, at places has platy jointing. The upper rubbly surfaces of some flows are not completely filled or sealed by succeeding flows. Water is contained in and moves through the interflow zones, and the unit yields moderate to large supplies of water where several permeable interflow zones are penetrated. Large yields are obtained at many places in Whitman and Adams Counties, Washington, and at a few places in Idaho; however, interfingering fine-grained sedimentary strata reduce the permeability at some places. These strata are more numerous near the margins of the basalt plateau, as in Idaho. Also, much of the area that is underlain by basalt is high above the major streams, and at some places the water table is many hundreds of feet below the land surface, so that high pumping lifts are required.

The other extensive aquifer units, the Challis volcanics (Tcv) and the pre-Tertiary rocks (pT), yield small or moderate supplies to wells and springs for domestic and stock use, and for a few small public supplies. Fractured crystalline rocks and coarse grained sedimentary and pyroclastic rocks may yield moderate supplies at some places. A deep weathered zone, together with talus and colluvium, forms a large porous and permeable shallow ground-water reservoir in the mountains of Idaho that maintains a high base flow in the Salmon and Clearwater Rivers.

Brief descriptions of the aquifer units, their hydrologic characteristics, and the quality of the water yielded by them are given in table 234. The general availability of ground water is shown on the map, figure 422. For maximum utility, that map and the aquifer-unit map, figure 421, should be used together.

Many areas of alluvium (Qal) and basalt of the Columbia River Group (Tcr) are designated "yield unknown" because information is lacking on which to estimate the yield of wells. Probably at many places wells in the alluvium would yield 100 to 2,000 gpm, and wells in the basalt would yield 20 to 500 gpm.

Water in Storage

A rough estimate of the quantity of water stored in each aquifer unit, in a specified depth interval below the water table, is given in table 235.

Table 234. Description of Aquifer Units and Their Hydrologic Characteristics, Subregion 6

Map Symbol and Geologic Relations	Lithologic Description	Hydrologic Characteristics	Water Quality
Qual: Stream alluvium, glacial outwash, and basin fill of Quaternary and Holocene age. Includes fluvio-lacustrine deposits in Grand Ronde Valley. Deposits in many narrow valleys not shown on map.	Stream alluvium and glacial outwash, poorly to moderately well-sorted coarse sand and gravel underlying present floodplains and terraces. Some lenses of fine to medium sand. Fluvio-lacustrine deposits range from sand and gravel to fine sand, silt, and clay	Stream terrace deposits and floodplain alluvium yield moderate to large supplies where 10 to 50 feet or more of sand and gravel lie below the water table. Yields of 10 to 100 gpm commom from shallow wells; 500 to more than 1,000 gpm can be obtained from larger, deeper wells. Fine-grained lacustrine deposits yield less.	Generally calcium bicarbonate water; dissolved solids less than 250 mg/1, water soft to moderately hard; low fluoride and iron.
Tcr: Basalt flows and interbeds of the Columbia River Group.	Basalt and basaltic andesite in flows generally between 25 to 100 feet thick. Lower part of flow dense, massive columnar jointing; upper part frequently scoriaceous, vesicular; at places has platy jointing. Pyroclastic and tuffaceous water-laid sedimentary interbeds.	Larger part of individual flow has low porosity and permeability. Uppermost few feet of some flows and the zones at their contacts with overlying flows commonly are porous and permeable. Where several permeable interflow zones are penetrated, wells yield a few hundred to several thousand gallons per minute. Fine-grained sedimentary deposits between flows reduce permeability of interflow zone.	Chiefly calcium bicarbonate water; dissolves solids less than 300 mg/1; water soft to moderately hard. Sodium adsorption ratio generally low, rarely exceeds 2.5 mg/1.
Tv: Andesitic volcanic rocks occupying about 100 sq. mi. southeast of La Grande. Miocene in age.	Andesite tuff breccia, welded tuff, andesitic lava flows and interbeds of cross-bedded sandstone and siltstone.	No information on wells available. Appear to be relatively impermeable, probably will yield only small quantities of water.	No data available.
Tcv: Challis Volcanics of Eocene and Miocene age, in Idaho.	Lava flows and pyroclastics ranging from rhyolitic to basaltic in composition.	Very little information available. Permeability generally low and unit will yield only small supplies; moderate to moderately large supplies may be obtainable at some places.	No data available.
pT: Rocks of pre-Tertiary age; includes Precambrian, Palezoic and Mesozoic rocks.	Precambrian metamorphic rocks, Paleozoic limestone, and other sedimentary strata; late Paleozoic-early Mesozoic metavolcanics and Mesozoic-Tertiary granitic to dioritic intrusives.	Little information available. Probably will yield only small supplies at most places. Weathered zone on Tcv and pT, and talus and colluvium forms a shallow ground-water reservoir that maintains a high base flow in mountain streams.	Shallow water generally low dissolved solids; soft to moderately hard. Some highly mineralized hot water rises along faults and discharges from springs.

A depth interval of 100 feet was used for the Columbia River Group which underlies broad plateau areas where the water table conceivably could be lowered considerably. The same depth interval was used for the Tertiary volcanic rocks (Tv). A depth interval of 50 feet was used for the three other aquifer units.

Table 235 - Storage, Recharge, and Discharge of Ground Water in Aquifer Units, Subregion 6

Aquifer Unit	Area		Storage			Annual Natural Recharge and Discharge	
	Sq. Mi.	Acres (1000's)	Specific Yield (percent)	Depth Used (ft)	Water (1000's ac-ft)	Inches Over Area	(1000's ac-ft)
Qal	1,690	1,080	20	50	10,800	12	1,080
Tcr	12,800	8,200	1	100	8,200	4	2,700
Tv	95	61	1	100	60	4	15
Tcv	2,620	1,675	1	50	840	4	560
pT	17,900	11,400	2	50	11,400	5	4,750
TOTAL (rounded)	35,000	22,000			31,000		9,000

The specific yield of the alluvial deposits was estimated to be 20 percent. The upper 50 feet of saturation in the pre-Tertiary aquifer unit (pT) is partly in the weathered soil and subsoil. The specific yield may be as much as 5 or 10 percent in the weathered zone, but less than 1 percent in the unweathered rock. An average specific yield of 2 percent was used to calculate the amount of water in the upper 50 feet of saturated rock. A specific yield of 1 percent was assumed for all the volcanic aquifer units (Tcr, Tv, Tcv). It is estimated that about 31 million acre-feet of water is stored in the specified depth interval (table 235). Storage in the two aquifer units utilized extensively (Tcr, Qal) is about 19 million acre-feet. Most of the remainder is in the pre-Tertiary aquifer unit (pT).

Natural Recharge and Discharge

Recharge to aquifers in Subregion 6 is derived chiefly from direct precipitation and snowmelt, but at some places by influent seepage of streamflow and irrigation diversions. There are no diversions of ground water into the basin; however, a small amount

may move westward in Franklin and Adams Counties into Subregion 2, and southward in Columbia County into Subregion 7.

Recharge to the alluvial aquifers is partly from direct precipitation on the area of outcrop, but is mostly from irrigation diversion and influent seepage from streams. Annual ground-water discharge from the Lemhi and Pahsimeroi Valleys is equivalent to a recharge of about 9 inches over the area occupied by the alluvial deposits. Precipitation in those two valleys is lower than in most of the rest of the subregion, and recharge to the alluvial deposits is less than in most other basins. In some narrow valleys, recharge to and discharge from the terrace deposits and flood-plain alluvium may be equivalent to an annual recharge of 24 inches over the area of outcrop. An estimated average value of 12 inches of natural recharge over the entire area occupied by the alluvial deposits was used in table 235.

The basalt of the Columbia River Group (Tcr) underlies several broad upland or plateau segments separated by major streams flowing in deeply incised canyons. Tributary streams within the plateau segments are commonly much less deeply incised. At places the regional water table is several hundred feet below land surface and many of the smaller streams lose water to the water body in the basalt. Throughout much of the area the basalt is overlain by Palouse silt ranging in thickness from several feet to possibly 100 feet and at some places there are perched aquifers in the silt. The silt is very porous but has low permeability. Therefore, it supplies effluent seepage to streams and accepts and transmits recharge to the basalt. Thus, the basalt is recharged by precipitation and snowmelt directly on the basalt, especially where erosion has exposed interflow zones; by downward seepage through the silt; and by influent seepage from streams that are above the water table. Because the central parts of the individual basalt flows are dense and impermeable, recharge perpendicular to the flow surface is negligible except where the flow is broken by jointing or other fracturing. For the most part, recharge probably is directly into the interflow zones and is restricted in broad plateaus where the flows are parallel to the land surface.

Hydrographs and flow-duration curves for streams draining the basalt in subhumid areas flanking the Blue and Wallowa Mountains were used to determine the ground-water component of discharge. The data indicate that the annual ground-water discharge from the basalt and overlying Palouse silt in those areas is equivalent to 4 to 12 inches of recharge over the drainage area. In the semiarid parts of the subregion, recharge to the basalt is much less; and probably is less than 1 inch a year in the extreme western part of the subregion in Washington. Four inches were used for estimating annual natural recharge and discharge of aquifer units Tcr and Tv in table 235.

The pre-Tertiary unit (pT) and Challis volcanic rocks (Tcv) chiefly underlie mountainous areas where precipitation ranges generally from 30 to 60 inches. Recharge to those units is entirely from precipitation and snowmelt during the fall, winter, and spring months. A study of stream hydrographs indicates that ground-water runoff from these areas ranges generally from 4 to 8 inches annually. Arbitrary values of 5 and 4 inches were assigned to the pre-Tertiary and Challis volcanic rocks, respectively, for average annual natural recharge and discharge.

The estimated total annual natural recharge and discharge from aquifers in Subregion 6 is 9 million acre-feet (table 235). However, much of the water that becomes recharge to the alluvium, and to a lesser extent to the basalt, has already been through the ground water-surface water cycle in the basin. Probably the net annual recharge and discharge is closer to 8 million acre-feet. A rough check on this figure can be made by totaling the average annual ground-water component of flow for major streams draining the subregion: the total exceeds 10,000 cfs, or 7.25 million acre-feet a year.

Annual Ground-Water Withdrawal

Ground-water withdrawal (table 236) amounts to approximately 80 thousand acre-feet a year, about 1 percent of the estimated natural recharge and discharge from aquifers in the subregion. Most of the withdrawal is from the alluvial and glacial deposits (Qal) and basalt of the Columbia River Group (Tcr).

Chemical Quality of Water

Generally, the chemical character of the water is good to excellent for all uses. Dissolved solids are usually less than 300 mg/l; the water is chiefly of the calcium bicarbonate type and is soft to moderately hard. Rarely are there excessive concentrations of constituents that cause hazards or problems. A few wells in the basalt (Tcr) have sodium exceeding 50 percent of the cations, but the sodium adsorption ratio rarely exceeds 2.5. Iron and fluoride usually are low.

As in Subregion 5, Subregion 6 has a large number of thermal springs. There are about 110 spring locations listed by Waring (196) nearly all in Idaho. Some entries represent 10 or 15 individual springs; therefore, there must be thousands of thermal springs in Subregion 6. Most of these issue from granite; a few issue from other pre-Tertiary rocks (metamorphic rocks, limestone, etc.); and a few from Tertiary volcanic rocks (Tcr or Tcv) near the contact with pre-Tertiary rocks. Most of the

Table 236 - Estimated Ground-Water Withdrawal and Consumptive Use, Subregion 6, 1970

	Ac-ft per year; all quantities in thousands			
	Idaho	Oregon	Washington	Total
Irrigation				
Acres irrigated	1.2	4.0	6.4	11.6
Withdrawal	3.6	12.0	19.0	34.6
Consumptive use	1.8	6.0	9.5	17.3
Industrial[1/]				
Withdrawal	2.3	2.5	1.8	6.6
Consumptive use[2/]	.1	.1	.1	.3
Public Supplies				
Persons served	46.0	10.0	45.0	101.0
Withdrawal	12.3	2.4	11.0	25.7
Consumptive use[3/]	2.5	.5	2.2	5.2
Rural Domestic				
Persons served	32.0	10.0	28.0	70.0
Withdrawal[4/]	3.6	1.1	3.1	7.8
Consumptive use[5/]	1.8	.6	1.5	3.9
Stock				
Withdrawal and consumptive use[6/]	1.95	.20	1.56	3.71
TOTAL WITHDRAWAL (rounded)				80.0
TOTAL CONSUMPTIVE USE (rounded)				30.0

1/ Self-supplied industrial
2/ Assumed to be 5 percent of gross withdrawal.
3/ Assumed to be 20 percent of gross withdrawal.
4/ Estimated use 100 gallons per day per person.
5/ Assumed to be 50 percent of gross withdrawal.
6/ Assumed that all water withdrawn is consumed.

thermal springs appear to be related to fault zones in or near the Idaho granitic batholith. Few chemical analyses have been published, but some of the water is highly mineralized. Probably most of this water is of the sodium bicarbonate type and, at some places, may have very high fluoride concentrations (180).

Present Use and Future Availability

Estimates of ground-water withdrawal and consumptive use in 1970 are given in table 236. Total annual ground-water withdrawal is about 80 thousand acre-feet and consumptive use is about 30 thousand acre-feet. Nearly all of the withdrawal and use are from alluvial deposits (Qal) and basalt of the Columbia River Group (Tcr). A part of the water not consumed returns to the streams, so net withdrawal of ground water may be on the order of 40 thousand acre-feet per year, about 0.5 percent of the estimated average annual natural recharge and discharge. Thus, present withdrawal and use is insignificant on a subregionwide basis. However, pumpage is concentrated in some areas and, as is usually the case, in some of those areas recharge is relatively low.

Present development of ground water from the alluvial deposits is small in total quantity and is widely dispersed. Large additional amounts are available in such basins as the Pahsimeroi, Lemhi, and other valleys in the Salmon River drainage, the Grande Ronde Valley, and segments of the Wallowa River Valley near Wallowa and Enterprise. Moderately large to large yields can be obtained from the alluvial deposits in many of the narrower valleys, but because of the limited areal extent of the deposits, development of supplies requiring several wells of large capacity generally would be dependent upon inducing recharge from a nearby surface-water supply, such as a river or lake.

Development of ground-water supplies from the Columbia River Group is comparatively small, perhaps about 50,000 acre-feet a year. Use for domestic, stock, and public supply is widely dispersed. Use for irrigation is concentrated in the Grande Ronde Valley and in the area north of the Snake River in Washington. In the latter area, annual recharge is much less than average for the aquifer unit, possibly less than 1 inch. Large additional supplies of ground water are available from the basalt at many places; however, the great depth to water at some places, as, for example, south of the Snake River in Walla Walla County, and small recharge in some areas, limit the potential for development. A large number of faults and other structures have divided the basalt into many compartments, each of which has its own ground-water regimen.

Detailed studies will be required to delineate the structures in order to determine where large supplies of ground water can be obtained.

Artificial Recharge

So far as is known, there is no artificial recharge of aquifers in Subregion 6. The alluvial deposits (Qal) are in valleys and basins where natural recharge is relatively high; withdrawal of large quantities of water would induce an even larger natural recharge at most places. It does not seem probable that artificial recharge of these deposits will be needed in the foreseeable future.

Natural recharge to the basalt aquifers (Tcr) is low at some places. Water levels have had a long history of decline in the Pullman-Moscow area (35, 151), and as shown by hydrographs in figure 423. The report by Foxworthy and Washburn (36) discussed the possibility of artificial recharge, and concluded that recharge through injection wells was feasible (43). No doubt, artificial recharge of the basalt in other areas where the water table is low and natural recharge is limited also is feasible where a suitable supply of water for recharging is available.

Water Rights

Idaho

A very high percentage of the subregion in Idaho is mountainous and little or no ground-water development has occurred. There are a few water rights on file along the Salmon River near its headwaters associated with the development of the communities of Stanley, Challis, Leadore, and Salmon. This development is primarily for small wells for domestic water rights.

Well development has also occurred in the Camas Prairie near the communities of Grangeville, Cottonwood, and Craigmont. Some of this development has led to the establishment of irrigation rights but quantitative figures are not available at this time.

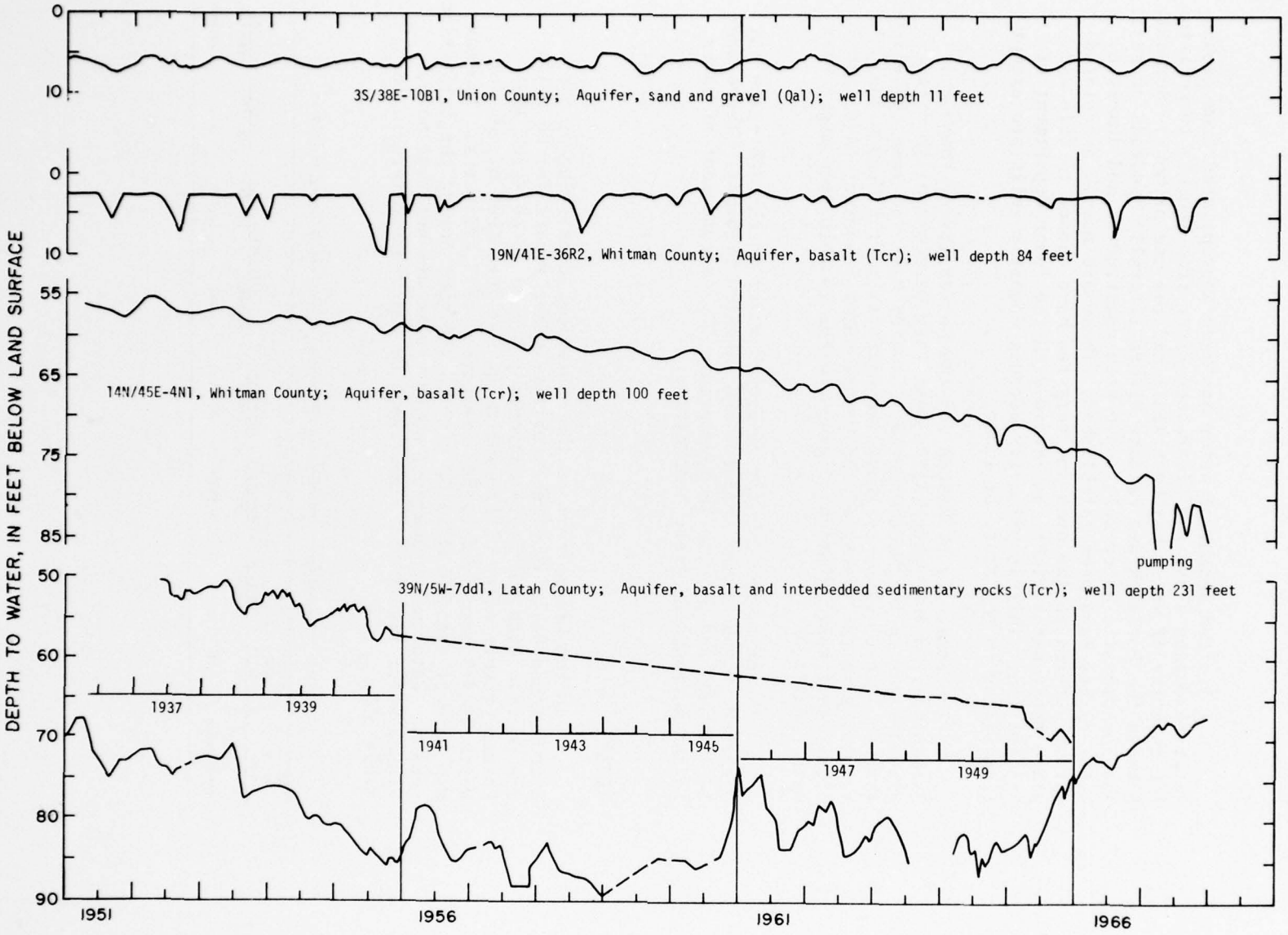


Figure 423 Hydrographs of selected wells in subregion 6

A limited amount of water has been appropriated from ground-water resources along the Clearwater River from Kooskia to Lewiston. The quantity of water has been small and the use primarily domestic. Between the Potlatch and Palouse Rivers literally hundreds of small, shallow domestic water wells have been constructed and domestic water rights have been established. These are mostly associated with the farms in the area and very few have chosen to file and place their water rights on record with the Idaho Department of Reclamation. This is primarily because domestic wells are exempt from filing in the State of Idaho.

The community of Moscow and the University of Idaho rely exclusively on the water rights that they have established for ground-water in the Moscow Basin. Studies have led some to believe that the use of water by these two entities in the Moscow Basin is resulting in the mining of the ground-water resource. Additional significant appropriation of ground water in this area might meet with opposition.

The major development of ground water in the subregion has occurred in and around Lewiston and Lewiston Orchards. There are 14 licenses and permits to appropriate 37.3 second feet of water in and surrounding these communities.

Oregon

In the Oregon part of the subregion, consisting of the Grande Ronde Basin in Oregon, primary water rights for 66 wells are on file with the State Engineer's Office as of March 1967. Primary rights allow withdrawal of 20,562 acre-feet a year, of which 10,479 acre-feet is for irrigation of 3,492 acres. The maximum rate of withdrawal is 52 cfs (23,400 gpm) during the irrigation season. Data on supplemental water rights are not available. Ground-water rights are summarized, by major-use category, in table 337.

Table 237 - Summary of Ground-Water Rights in the Oregon Part of Subregion 6, 1967

Basin No. & Name	Number of Wells	Domestic (ac-ft)	Municipal (ac-ft)	Industrial (ac-ft)	Irrigation (acres)	Irrigation (ac-ft)	Other (ac-ft)	Total (ac-ft)
8 Grande Ronde	71	0	6,596	3,487	3,492	10,479	0	20,562

Washington

In the Washington part of the subregion, essentially Water Resource Inventory Areas 33 through 35 (figure 360), a total of 256 active ground-water right appropriation and declaration records, in permit and certificate stages, were on file with the Department of Water Resources as of September 30, 1966. Prime rights in this area allow summer period consumptive withdrawals totaling 114,487 gpm (255 cfs). No supplemental ground-water rights were on record for this subregion.

Prime water right quantities for the more important use categories and total actual ground-water right quantities are listed in table 338, according to Water Resource Inventory Areas as defined by the State of Washington, Department of Water Resources. (Regional Summary) More detailed information about specific rights can be obtained from the Department of Water Resources.

Table 238 - Summary of Ground Water Rights, Washington Part of Subregion 6, 1966

Basin No.[1]	River Basin	Municipal	Irrigation	Individual and Community Domestic	Industrial and Commercial	Fish Propagation	Stock	Total[2]
				(Gallons per Minute)				
33	Snake-Low	-	15,019	4,721	3,794	-	462	19,600
34	Palouse	7,617	46,367	22,162	550	-	12,359	59,674
35	Snake-Tucannon	19,699	14,809	2,779	10	-	1,000	35,213
TOTAL		27,316	76,195	29,662	4,354	-	13,821	114,487

1/ Water Resource Inventory Area number as shown in figure 360.
2/ Total prime right quantities do not agree with the sum of the uses because (1) only the more important use categories are listed and (2) water right quantities that are common to two or more uses are listed under each applicable use category.

RELATIONSHIP BETWEEN SURFACE AND GROUND WATER

In Subregion 6, aquifers discharge ground water to streams at most places except on the basalt plateaus. All major streams and many minor ones, have a continuous ground-water component of flow. All streams receive ground-water inflow in their reaches within the pre-Tertiary rocks. Some of the smaller streams lose part of their flow by seepage to the alluvial deposits (Qal) upon entering basins such as the Pahsimeroi and Lemhi Valleys. However, the ground water reappears in the trunk streams of these valleys. The total discharge of the Pahsimeroi River is almost entirely ground-water effluent, and the discharge of the Lemhi River probably is 80 to 85 percent ground water.

On the basalt plateaus, water from some reaches of many small streams recharges the underlying aquifers. However, streams that are incised deeply enough to be below the regional water table, receive effluent ground-water seepage throughout the year. Asotin Creek is an example of such a stream; probably more than 75 percent of the average discharge of the creek is derived from ground water.

The Clearwater and Salmon Rivers are the largest streams originating in the area. The ground-water component is about 30 percent of the average annual discharge of the Clearwater River and 40 percent of the flow of the Salmon River. Basins of both rivers are underlain chiefly by pre-Tertiary rocks. The higher percentage for the Salmon River probably is due to the large amount of ground-water effluent from alluvial deposits in the headwaters of the Salmon River. According to curves given by Simons (144), winter base flow in the Salmon River at Whitebird rarely is below 4,000 cfs and summer base flow rarely is below 2,000 cfs. The curve for winter base flow shows that 120 days would be required for base flow to decline from about 8,600 to 3,800 cfs. There probably are several reasons why the minimum base flow in winter is higher than in summer. These may include the following:

1. The ground water is maintained at higher levels during the winter than in summer and fall because of concurrent recharge, whereas there is little or no recharge during the summer and fall.

2. Water loss by evapotranspiration of vegetation along the stream courses probably greatly reduces the amount of ground water appearing in the streams during summer months.

Low-flow characteristics of two streams are shown in figure 424.

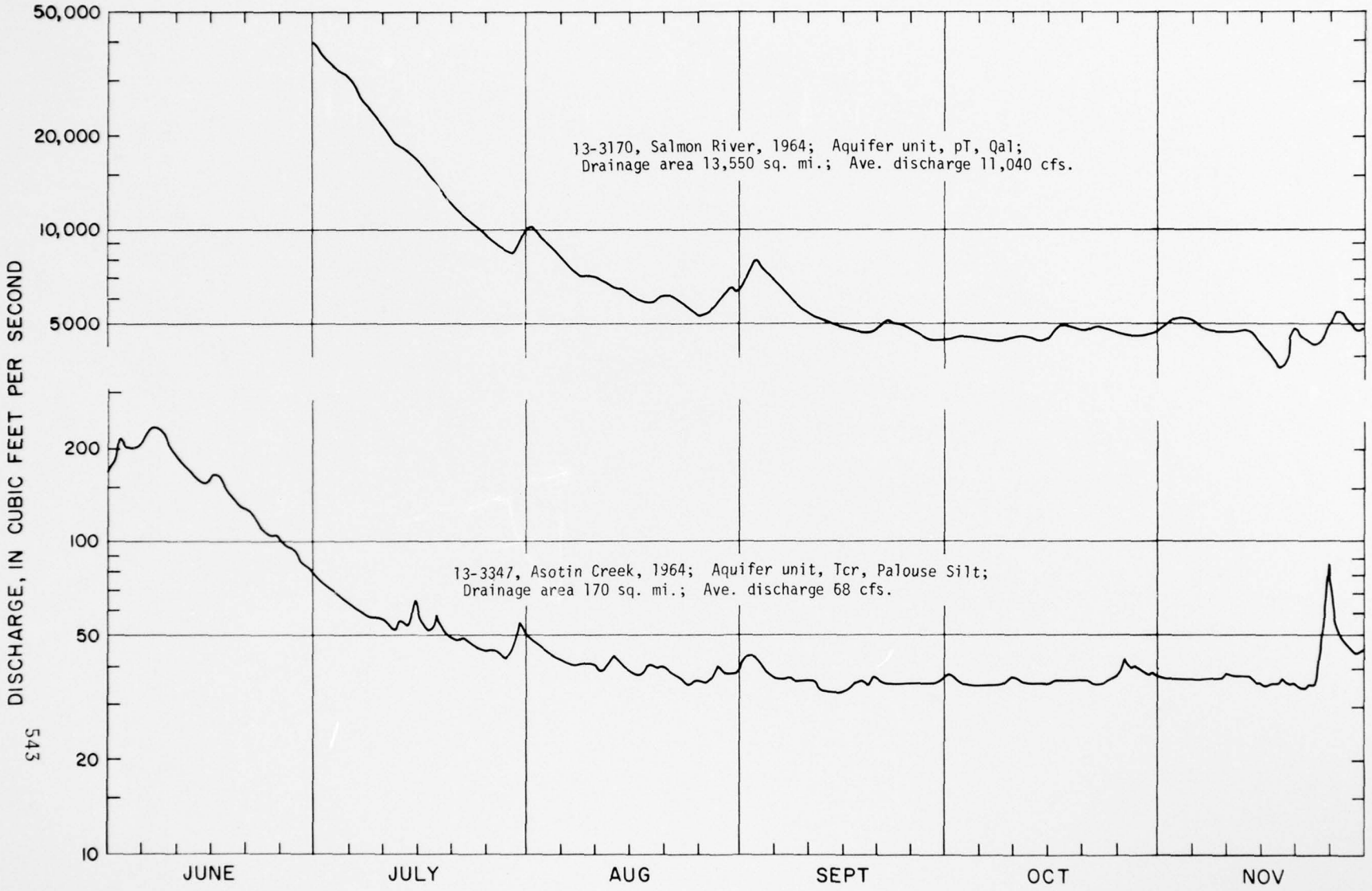


Figure 424 Hydrographs showing low-flow characteristics of selected streams

PARTICIPATING STATES AND AGENCIES

STATES

Idaho	Nevada	Utah	Wyoming
Montana	Oregon	Washington	

FEDERAL AGENCIES

Department of Agriculture
- Economic Research Service
- Forest Service
- Soil Conservation

Department of the Army
- Corps of Engineers

Department of Commerce
- Economic Development Administration
- Weather Bureau

Dept. of Health, Education, & Welfare
- Public Health Service

Dept. of Housing & Urban Development

Dept. of Transportation

Department of the Interior
- Bonneville Power Administration
- Bureau of Indian Affairs
- Bureau of Land Management
- Bureau of Mines
- Bureau of Outdoor Recreation
- Bureau of Reclamation
- Fed. Water Pollution Control Adm.
- Fish and Wildlife Service
- Geological Survey
- National Park Service

Department of Labor

Federal Power Commission